1982 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

HEARINGS

BEFORE THE

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SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

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SCIENCE AND TECHNOLOGY
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*On assignment to Budget Committee for 97th Congress.

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1982 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

WEDNESDAY, JANUARY 28, 1981

House of Representatives,
Committee on Science and Technology,
Washington, D.C.

Mr. Fuqua. The committee will be in order.

We will be hearing the testimony from representatives of the National Science Foundation. We hope to get an overview of their major programs and an assessment of their targeted budget for the coming fiscal year.

A total of $1.35 billion has been proposed in the current budget for fiscal year 1982. This represents an increase of $257.5 million or 23.5 percent more than the level of the current plan for fiscal year 1981.

A number of changes and initiatives are being proposed by NSF, not the least of which is a reorganization of the Foundation's applied sciences and engineering programs. As I understand it, the Foundation is taking a new management approach by relating applied research more closely to the programs of basic R. & D. Hopefully, such a change will lead to a more vigorous development of the technical knowledge necessary for innovation and, thus, national economic growth.

This committee has taken for some time a strong interest in the problems of innovation and the need for developing a stronger, more competitive economy through our scientific and technological capability. Our studies indicate that the Foundation holds a key position in determining the direction and magnitude of applied, as well as fundamental R. & D. in the various research institutions of this country.

We will be maintaining a strong interest in the Foundation's proposed increased emphasis on engineering research, as well as the effects of other organizational changes under way.

Scientific and engineering education are also assuming increasing importance to this country's basic well-being. A major report issued last year by the Foundation together with the Department of Education notes important deficiencies in both the quality and quantity of engineers and various scientific professionals. Raising general scientific literacy, to achieve a technologically sophisticated work force and voting public, is also being widely stressed. The Foundation has responded with major initiatives for upgrading of instructional engineering equipment, improving research instrumentation and facilities, and establishing needed traineeship for engineering graduate studies.

We will examine with some care the Foundation's proposals in these areas. Certainly strong support must be established and maintained on a long-term basis in order to reverse the current negative trends of our scientific and technical education progams.

Finally, the current proposed budget calls for a number of interesting and important changes:

Increasing support for fundamental research by 14 percent to a total of $1,056.6 million;

Expanding of small business R. &. D progams for innovation and commercial applications from $7.5 million to $14.5 million;

Continuing development of the ocean margin drilling program through a proposed 45 percent increase of $11 million to $16 million, and,

Development of initiatives to provide increased opportunities for women and minorities in science and engineering.

I look forward to hearing further about these programs and other concerns of the Foundation this afternoon.

I would like to ask if Mr. Winn has any comments he would like to make at the beginning of the hearing.

Mr. WINN. Thank you, Mr. Chairman.

No, I do not have any prepared remarks. I would just hope since we have some new people appearing before the committee that the board, with the fine reputation that you would enjoy, could ward off some of the articles about the studies that you make and feature stories that we usually see in the Reader's Digest due to some of the fantastic titles of the studies that you make. I think we are not critical of them because we study them but it makes for good writing, some of the manuals by the columnists and newspaper writers. I hope either you can develop a title that really basically explains what the studies are, or clarify it in some way. But I want to congratulate you on the work you have done in the past.

Thank you.

Mr. FUQUA. I think that was taken care of in some language that we had in the bill last year initiated by your colleague, Mr. Hollenbeck of New Jersey. We will be anxious to see how that is being implemented as the hearings progress more specifically in the subcommittee.

Congressman Brown, who because of illness could not be here today, asked if he would be permitted to insert a statement in the record at this point. Without objection, that permission will be granted.

[The prepared statement by Congressman Brown follows:]

STATEMENT BY HON. GEORGE E. BROWN, JR.

One cannot help but be pleased with the budget numbers and programs as proposed for NSF by the outgoing Administration. The overall budget is increased by 23.5 percent.

Among the highlights: A much needed university research equipment and laboratories program for $75 million is proposed. Fundamental and applied research have increased by substantial amounts. Though I could argue that the 10.6 percent increase in applied research is insufficient, the Foundation, through its reorganization and other activities, apparently recognizes the increasing importance of these programs. We see increases in the industry/university cooperative research programs, as well as the small business innovation program. Finally, the Foundation appears ready to deal with the problems and difference in scientific and engineerig education through a new $25 million instructional equipment programs and a $3 million traineeship progam.

Unfortunately we must must temper our enthusiasm with reality. The incoming Administration has made it clear that it will be making severe cuts in major government programs, including those of basic research and development. More specifically, the new head of OMB has stated a number of times that he felt cuts of $300 to $400 million, primarily in the areas of the Social Sciences and Science Education, could be and should be sustained by NSF. Some political currents would indicate that rather than see a healthy, strengthening of our basic and applied programs across the board at NSF, we are more likely to see a drastic cut back and retrenchment of the very programs that are necessary to the well-being and long-term economic health of this country.

As noted by our Chairman, my colleagues Mr. Fuqua, our studies on innovation and productivity indicate the extreme importance of basic R&D, as well as applied research aimed at enhancing our domestic and international competitiveness. Those studies also indicate the growing importance of human and social factors in innovation. Japan's increased productivity is not based solely in technological superiority but also on cultural, social and managerial factors. The understanding of these and related phenomena can only come from a strengthening and growth of the relatively neglected fields of social and biological sciences. The answer to our current economic problems will most likely come from these so called "soft" sciences, not through simply the development of more hardware or technology.

We must also understand and promote the role of women and minorities in science and engineering. The additions to our technical talent pool of these important segments of society can only aid in finding solutions to the many problems facing us.

I look forward to discussing these and other issues today, as well as in future hearings with NSF.

Mr. Fuqua. Dr. Langenberg, we would be happy to hear from you at this time, or Mr. Doan, whoever wishes to be first.

[The biographies of Dr. Langenberg and Mr. Doan follow:]

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

DONALD N. LANGENBERG
Deputy Director

Donald N. Langenberg was born March 17, 1932 in Devils Lake, North Dakota. He received his undergraduate education at Iowa State University, received the M.S. degree from the University of California, Los Angeles, and the Ph.D. degree from the University of California, Berkeley.

He joined the faculty of the University of Pennsylvania in 1960, where since 1967 he has been Professor of Physics. He currently also holds a secondary appointment as Professor of Electrical Engineering and Science.

Dr. Langenberg is married to the former Patricia Warrington, who is Assistant Professor of Statistics at Temple University. They have four children: Karen, 25, graduate student in physiology, University of Pennsylvania; Julie, 23, student in the School of Veterinary Medicine, University of Pennsylvania; John, 18, student at Yale University; Amy, 16, student at Lower Merion High School, Ardmore, Pennsylvania.

Dr. Langenberg's field is experimental condensed matter physics and materials science. His earliest research was concerned with the electronic properties and Fermi surfaces of metals and semiconductors. A major part of his research career has been devoted to the study of the phenomenon of superconductivity, particularly the Josephson effect and nonequilibrium superconductivity. He is perhaps best known for his work on the determination of certain fundamental physical constants using the AC Josephson effect. One of the consequences of this work was the development of a new type of voltage standard which has been officially adopted by the United States and by other nations. Dr. Langenberg is the author or co-author of approximately one hundred scientific articles and has edited several books.

Dr. Langenberg has held predoctoral and postdoctoral fellowships from the National Science Foundation, the Alfred P. Sloan Foundation, and the John Simon Guggenheim Foundation. In 1975, he was awarded the John Price Wetherill Medal of the Franklin Institute. He has been a visiting professor or researcher at Oxford University, the Ecole Normale Superieure, the California Institute of Technology, and the Technische Universitat Muchen.

At the University of Pennsylvania, Dr. Langenberg has served as Associate Chairman for Undergraduate Affairs of the Department of Physics, Director of the Laboratory for Research on the Structure of Matter, and Vice Provost for Graduate Studies and Research. He has been Chairman of the Division of Condensed Matter Physics of the American Physical Society and is Chairman-Elect of Section B (Physics) of the American Association for the Advancement of Science. He has served as an advisor or consultant to a variety of universities and government

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agencies. He has been Chairman of the National Science Foundation Advisory Council and a member of the Board of Trustees of Associated Universities, Inc., of the Council on Governmental Relations, and of the National Commission on Research.

Since July, 1980, Dr. Langenberg has been Deputy Director of the National Science Foundation. He also served as Acting Director until December, 1980.

December 1980

HERBERT DOW DOAN

CHEMICAL ENGINEER

Born Midland, Michigan, September 5, 1922; son of Leland Ira and Ruth (Dow) D.

Student Cranbrook Preparatory School, 1937-41; B.Sc. in Chemical Engineering, Cornell University, 1949.

Technical service and development, Dow Chemical Company, Midland, Michigan, 1950; purchase analyst, 1951-52; executive research, 1953-56; manager, chemistry department, 1956-60; executive vice president, 1960-62; president, 1962-71; presently director.

Partner, Doan Associates, Midland; chairman, Doan Resources Corporation Midland; director, Centennial Corporation, Grand Rapids, Michigan; Interactive Systems, Inc., Ann Arbor, Michigan; Fitterer Engineering Associates, Inc., Pittsburgh; Dow Corning Corporation, Midland; Omnitext, Inc., Ann Arbor; Chemical Bank and Trust Company, Midland; Process Computer Systems, Inc., Flint; Progressive Dynamics, Marshall, Michigan; president, Michigan Foundation for Advanced Research, Midland; incorporator, Neuroscience Research Foundation, Brookline, Massachusetts.

Member board fellows Saginaw Valley College; advisory council, Graduate School Business Administration, Michigan State University; member, Cornell University Engineering Council; advisory board, Department of Chemical Engineering, University of California at Berkeley; trustee, Dow Foundation; Fellow, Metaphysical Society, Midland; member, American Institute Chemical Engineers, American Chemical Society, Manufacturing Chemists Association.

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Excerpt from WHO'S WHO IN AMERICA, 37th Edition, 1976-1977.

STATEMENTS OF DR. DONALD N. LANGENBERG, DEPUTY DIRECTOR, NATIONAL SCIENCE FOUNDATION, AND HERBERT D. DOAN, VICE CHAIRMAN, NATIONAL SCIENCE BOARD, AND CHAIRMAN, DOAN RESOURCES CORP., MIDLAND, MICH.

Dr. LANGENBERG. Thank you, Mr. Chairman.

I am pleased to have this opportunity to appear before this committee, and to present to you an overview of some of the more salient features of the Foundation's proposed programs for fiscal year 1982. I very much regret that Dr. John Slaughter, who was sworn in last month as the new Director of NSF, isn't able to be here today.

Mr. Chairman, this committee has had a long association with the Foundation, so I think I need not review for you our fundamental missions and our procedures in support of science, engineering, research, and education. The unique mission, however, of the Foundation to support research and to be concerned generally with the health of science across all disciplines may perhaps bear repeating and emphasizing. This mission is in contrast to the mission of other agencies of the Federal Government with substantial research efforts, for each of these agencies has a particular and specific mission to perform and must structure its research accordingly.

As you know, the Foundation does its work primarily through grants to colleges, universities, and other research performers. It has no research laboratories of its own. It has, therefore, a very small staff headed by Dr. Slaughter as Director, with overall policy for its operation set by the National Science Board.

This Board is unique in Government, being composed of distinguished academic and industrial scientists and administrators who are appointed by the President to serve on a part-time basis in determining the fundamental policies of the Foundation.

I am very pleased to have with me today Mr. Herbert D. Doan, Vice Chairman of the National Science Board. With your permission, I would like to turn to him now to ask him to provide you with additional information concerning the National Science Board's responsibilities.

Mr. FUQUA. Mr. Doan, we are very happy to have you here with us today, and are very pleased that you could represent the Science Board, which is a very integral part of the National Science Foundation. We think they contribute greatly to the service to our country and its day-to-day operations. We are very happy to have you here today.

Mr. DOAN. Thank you. It is a pleasure for me to be here. I am substituting for Dr. Louis M. Branscomb, Chairman of the Board, who could not be here.

Mr. Chairman, if I might, I would offer as a part of your record the testimony that Dr. Branscomb made on Monday to the Senate Subcommitee on Industrial Growth and Productivity of the Budget Committee. It is a good statement on scientific research in academia and industry, and I think it should be part of your record.

Mr. FUQUA. We will include that in the record.

[The information follows:]

TESTIMONY OF DR. LEWIS M. BRANSCOMB, VICE PRESIDENT AND CHIEF SCIENTIST, IMB CORP.

My name is Lewis M. Branscomb. I am Vice President and Chief Scientist of the IBM Corporation. I serve as Chairman of the National Science Board, the policy making body of the National Science Foundation, and from 1969 to 1972 I was Director of the National Bureau of Standards in the Department of Commerce. I am pleased to be able to participate in this hearing on a topic of great importance and widespread interest in this country.

Since our introductory remarks are to be very brief, I would like to put my remarks in the context of a series of rhetorical questions, to which I will outline very brief answers, in the interest of guiding and stimulating the discussion which my colleagues and I will be having with the committee.

1. What is the state of health of the U.S. electronics and computer industries?

In comparison with the historical performance of other industrial sectors, by every measure these are extraordinarily healthy and successful industries. Gleams in the scientist's eye as recently as 30 years ago, the U.S. data processing industries produce $70 billion dollars of revenue for our economy here and abroad, exhibit a longterm growth rate of 13 percent, employ 700,000 workers in their American operations and are generating new jobs at roughly the rate of 50,000 per year. They are industries whose profitability has financed much of their own growth and at the same time attract a substantial amount of equity capital, financing hundreds of new business entries into the industry every year. They are therefore extraordinarily competitive industries, as measured both by new entries and by rapidly falling prices in conjunction with performance and functional improvements, and they exhibit a remarkable rate of introduction of new technologies and new products.

Any industry exhibiting this kind of technological and business dynamism is always in a state of change, and there are always challenges to be faced. As we move into the next generation of microelectronics technology, we will find the cost of entering the microelectronics business rising because of the great complexity and cost of production tooling. End-user product manufacturers will find the technical complexity of designing products in the most advanced technologies a substantial challenge. We therefore see many companies moving towards a verticallyintegrated capability, that is, the ability to make both microelectronic components and to deliver enduser products incorporating them.

A third measure of the state of health of this industry is the extraordinary attention being paid by the governments of other nations to developing their own competitive capability. These competitive challenges are a compliment and testify to the success of an industry whose roots lie within American ingenuity and business leadership.

2. Is this health driven by technological progress or by market opportunity?

The answer to this often-asked question is "both." Neither factor alone can keep the industry healthy. Scientific and technological progress has permitted the production cost of a given electronic function to fall annually by more than 26 percent, on the average, for 25 years. This falling cost, reflected in a highly competitive industry by prices falling at the same rate, both permits and requires volume growth in electronic shipments. This aggregate volume of shipments has grown faster than unit costs have fallen. That is, the demand elasticity for electronic and computer products has exceeded the technology's productivity gains and has led to very large growth in the physical volumes of manufactured goods and to net revenue growth in the industry. An industry with revenues growing at 13 percent which enjoys a technology price/performance improvement trend of 27 percent, is thus delivering 40 percent more computational power or other electronic capability to its customers every year, reduced perhaps to 30 percent by inflation.

Thus, the U.S. industry as a whole is exhibiting a real growth of more than 13 percent per year minus the penalty of inflation. Unless this real growth continues, the demand will not be sufficient to generate the revenues that permit the reinvestment in technology that will continue the price/performance trend.

3. What could threaten the health of this industry?

Fundamentally, it would be a failure of the upward spiral of growth in which customer demand more than compensates for the ability of technology to reduce prices. This upward spiral could turn into a downward spiral in which volume growth fails to produce revenue to cover falling prices. Then, companies would only be able to hold the profit margin needed to keep the technology going by cutting back on employment, and revenues would fail to generate capital to buy the tools to exploit the technology. Such a failure could occur for any of the following reasons:

(a) Failure of the technology to continue to sustain its rapid advance.

(b) Appearance of obstacles to demand-growth, such as government regulatory restrictions or a shortage of computer skills.

(c) Factors that unreasonably escalate costs (such as inflation, cost of capital, or tax increases).

(d) Failure to compete internationally, for whatever reason.

4. What is the current and prospective Japanese position in this industry?

The Japanese certainly are our most rapidly advancing competitors. At the present time, their penetration of U.S. computer sales is modest, but they enjoy enormous success in consumer electronics broadly. They are just beginning to be a significant factor in the U.S. semiconductor industry. They do have a way to go, and there is no reason to panic. In Japan itself, only last year did a Japanese company exceed IBM's wholly-owned Japanese subsidiary in domestic gross revenue.

There is no reason for complacency, however, for the Japanese rate of technical progress is truly impressive. In terms of integrated circuit components, the fundamental devices on which computer and consumer electronic products are based, Japanese shipments increased from 19 percent of the worldwide volume in 1977 to 24 percent in 1979 while exhibiting an average absolute compound growth rate of 56 percent. In the same period, Japanese investment in integrated circuit research and development has increased from $120 million in 1977 to $258 million in 1979, an average compound growth rate of 46 percent.

At the present time, IBM is the only company shipping 64,000 bit-per-chip memory devices in large volume, but I believe all of us are impressed by the quality of Japanese 16,000bit products, by their costs, and most importantly by the technology base they are building with which to challenge us both in components and in computers and other products in the mid-80's. There is little question that their rate of progress represents a serious challenge to the U.S.based industry.

5. What is the source of this extraordinary rate of progress in Japan?

It has many sources of which I believe the following four are most important:

(a) Japan focuses its priorities on sources of economic strength not weakness (as our government often seems to do). There is a national consensus in Japan that the information industry is to be one of the strategic industries on which the Japanese base their future. Every Japanese worker, government employee, and citizen understands that. They act accordingly.

(b) A focus of both government and industry in Japan on competition in technological terms. Market development is a longer-range priority. The Japanese seem to be able to forego near-term profitability in the quest for long-term strategic industrial position.

(c) The involvement of the Japanese government both in subsidizing key elements of the development of their industry, in orchestrating its components, in designing favorable tax and other financial arrangements for strategic industries, and in taking a very aggressive position supporting their companies' trade activities.

(d) By no means least important in this list is the quality and dedication of Japanese workers and management, the quality of their educational system and its production of engineers (twice ours), and the prestige which manufacturing technology and factory performance enjoy in the Japanese technical community.

6. Where does the U.S. industry's technology come from?

(a) Contrary to common belief, it does not come from government R&D expenditures or subsidies. The U.S. industry is largely financed by reinvestment of earnings in R&D and, in the case of small new enterprises, through investment capital. The IBM Corporation, for example, spent more than $1.36 billion in 1979 for R&D, all derived from our own earnings.

(b) The basic and applied research base of American universities, is still the strongest in the world. This of course is primarily a federal and state government investment. Unhappily, university research support has shown virtually no growth since the 1960's although Presidents Ford and Carter made strenuous efforts to reverse that stagnation and begin to rebuild the intellectual base for our national progress.

(c) In special cases, the technology has indeed come from defense and space requirements and highly specialized R&D programs dedicated to those requirements.

7. What has been the U.S. government role historically in this industry?

In the early years, the federal government's role was very important, for the computer industry was extensively stimulated immediately after World War II, which brought understanding of the computer's technological importance. However, it should be understood that even in the early years, the growth of the commercial computer industry and the invention and early development of the semiconductor industry originated in and were undertaken by private corporations.

Today the government's role is remarkably modest. The government purchases only about 8 percent of the domestic computer output, a figure down from 14 percent when I was Director of the Bureau of Standards in 1972. I also understand that the government only purchases about 7 percent of the output of U.S. semiconductor component manufacturers. Thus the government cannot claim that its activities as a consumer have important leverage on the industry. Indeed, President Carter's EDP study undertaken in the White House early in his administration painted a picture of general backwardness of U.S. government computer usage and often outdated equipment. The bright spots are in NSA, NASA, DOE and DOD, whose laboratories and technical programs generate requirements that push the state of the art.

8. What is the proper role of the U.S. government in this area?

The government has three very important roles which need to be carefully distinguished, for they call for different approaches. These are:

(a) Sustain a healthy economy under policies favorable to growth sectors. Here the important issues are the price and availability of capital, encouragement to capital investment in new plants and facilities, control of inflation, encouragement to R&D, and reasonable tax, patent, and antitrust policies. This is the most fundamental area of government responsibility.

(b) Provide effective support of U.S. business success overseas, understanding that our performance in overseas markets will heavily influence our ability to balance overseas business entries into the U.S. A global business also provides us a worldwide base of technology and experience which can be fed back into our own R&D and product planning.

(c) Support for the knowledge and skills on which industry builds for the future. That is, support for a competitive and highly proficient system of universities, colleges, and research institutions in the U.S.

9. What more specifically should be the U.S. government's role in R&D in relation to the microelectronic and computer industries?

I see four important roles for the government.

(a) The first is to acknowledge that special efforts that stress the state of the art, particularly by mission-oriented agencies such as the Department of Defense and NASA, are often justified and could well be expanded. The VHSIC semiconductor program in Defense, other Defense programs exploring new cryogenic and galium arsenide technologies, and special purpose computers that might, for example, obviate building giant wind tunnels all are examples worthy of careful study and vigorous implementation where justified. Many American universities are developing laboratories capable of exploring both the science and the engineering of very-large-scale-integration (VLSI) of electronic circuits. There may be justification for substantial federal support for the expansion of these laboratories. It is interesting to notice, however, that these laboratories are being generated largely with private and state money, and they have not turned yet to the federal government for broadbase support. This is a healthy development, but one the U.S. government should follow closely.

(b) The support of basic scientific and engineering research. This is clearly the one area of primary responsibility for the federal government, for only it can provide the scientific and engineering knowledge that the industry builds on. These are the programs of the National Science Foundation and the basic research support from the mission agencies. The most short-sighted thing we could possibly do in the effort to balance the federal budget would be to sacrifice the future technological capability of our industry by trimming dollars from our university research activities.

(c) Scientific and Engineering education is another sector where the government is playing much too small a role today and, unhappily, it is an area under heavy budget pressure. The recent report of the Science Foundation and the Department of Education to President Carter on scientific and technical education manpower clearly shows a crisis in engineering education, a crisis which the Science Foundation is attempting to address in its 1982 Program but which will require serious attention over a period of years. In essence, the problem is simply that we do not have enough faculty to provide engineers trained for advanced research and technology activities, nor is there adequate equipment in the universities to give these engineers a modern training. Similar problems exist in certain fields of science, of which the most critical is computer science. This committee has a very special responsibility to insure that those university programs of research and education are properly protected, in order to bolster a healthy economy in the future.

(d) Finally, but not the least important, is the federal role in encouraging university/industry research cooperation. This is an area where there are many excellent new ideas, and a whole new relationship between university and industry research is emerging. The National Science Foundation has a rapidly expanding program of cooperative research grants where a university and a company jointly propose a piece of work to be partly funded by the government, all of this work to be published and shared in the technical community. I personally believe we should go beyond this program and carefully examine an idea proposed but not acted on in the last Congress. This would be a tax incentive to companies to support research in universities. Such a proposal has the virtue of delegating to the universities and to industry the task of determining the topics upon which such a research should be performed and also keeps the government out of the negotiation over patents, licenses and the like. It would permit university students to become intimately acquainted with the kinds of technical challenges facing industry, and would give industry much broader access to the imagination and talent in our universities. The result could be to reduce substantially the time required for new scientific inventions to stimulate the creation of jobs for our people in a healthy competitive industry.

Mr. DOAN. I have served on the National Science Board since 1976. In 1979 I was elected to the Board's Executive Committee and in 1980 I was elected to be the Board's Vice Chairman. I am going to summarize my written comments in the interest of time for questions.

The NSF Act of 1950 assigns policymaking to the National Science Board and administration to the Director of NSF. The NSF in the broadest sense has the responsibility for the overall health of fundamental science in the United States. The National Science Board has 25 members including the Director of the Foundation who serves as an ex officio member.

Board members are appointed for 6-year terms by the President with the advice and consent of the Senate; eight members are appointed every 2 years. The result of a very wide selection process, the board is a balanced group with respect to background which includes hands-on-scientists, researchers, academic administrators, and industrialists. Also, attention is paid to the balance in terms of women, minorities, and geographical location.

The National Science Board carries out policymaking responsibilities largely through committees. The Planning and Policy Committee concerns itself with the long-term opportunities in science and engineering. Working these through our Budget Committee, the Board prepares multiyear cost estimates.

Incidentally, attached to my report is an update of the Status of Science Reviews—1980 called the Status of Science Reviews—1981 update. It might be of interest to you. It represents the judgments of the NSF program directors on the directions and opportunities in science and engineering supported through each of these directorates.

Oversight of the National Science Foundation activities is a major National Science Board responsibility and accomplished principally through the Programs Committee and the Audit and Oversight Committee. Also, this is done through Board member visits to NSF-supported facilities.

On January 15, 1980, the fiscal year 1982 National Science Foundation budget request was transmitted by President Carter to the Congress. The overall objective of this budget is to develop the strength and international competitiveness of the country's scientific and technological capabilities. The relationship of these capabilities to our industrial and military activity, as you know, is not always obvious but is very real. I will mention just a few thrusts that show up in the 1982 budget.

The first of these is support for instrumentation. A good deal of university equipment is obsolete, not up to industrial standards, nor competitive with foreign universities. The Foundation thinks there should be a considerable amount of money put in this area; also, that other agencies ought to share in this rebuilding program.

Engineering schools need upgrading, particularly in instructional equipment, giving the professors and students the best technology to work with, so that when students go into industry they will know what they are doing. Another emphasis is traineeships to encourage engineers to get doctorates so the United States in the future will have faculty available.

A major thrust of the program is mathematical and physical sciences; they get a substantial increase in fiscal year 1982. Within this area, materials research represents a need and an opportunity—studies on polymers, ceramics, metallurgy, composites—all these areas we feel are undersupported at the present time by the National Science Foundation.

We have had a program of industry-university cooperative research, and we propose to increase it. It is not going to represent, by any means, the thrust of the country in terms of university-industry cooperation, but we feel it is very useful catalytic money.

The chairman mentioned the ocean margin drilling program; it is not new but it will be considerably expanded in the 1982 budget. It has Government and petroleum industry participation. It represents a convergence of scientific goals, resource exploration and technological development which are quite timely. We hope this program will contribute toward establishing the scientific basis of the continental margins.

Those are all the remarks I will make. I want to express my appreciation for your past, present, and future support of the National Science Foundation and what it is trying to do.

Thank you, Mr. Chairman. Dr. Langenberg, would like to continue now.

Dr. LANGENBERG. Yes, Mr. Chairman, I would like to begin by discussing briefly our recent decisions on the internal organization of the Foundation to which you referred in your opening statement.

These decisions are reflected in the structure of our fiscal year 1980 budget proposal which was recently transmitted to the Congress. Last year when he appeared before this committee, Dr. Atkinson, former Director of NSF, noted, and I quote: "There has been a remarkable drawing together of basic and applied research."

A few months after Dr. Atkinson made that statement, the National Science Board asked the staff of the Foundation to undertake a study of the organizational implications of charging each directorate of the Foundation with the responsibility for supporting both basic and applied research within its disciplinary range.

We began that effort in July and by November, after extensive consultations both within the Foundation and with the scientific community outside, we were convinced that we could more efficiently and effectively carry out our legislatively mandated responsibilities if we established a Directorate for Engineering in lieu of our existing Directorate for Engineering and Applied Science, and, at the same time, assigned responsibility for the support of applied science throughout the Foundation to what some have thought of as the "basic" research directorates.

Our study led us to the conclusion that the traditional distinction between basic and applied research is often forced and artificial. Virtually all good research is potentially applicable. We all recognize it has been the source from which most modern high technologies have developed.

To give a couple of examples, one need to go back no farther than the study of DNA to find basic research which has led quickly to the development of technologies of enormous potential political, social and economic importance. One can equally well think of examples of research undertaken as applied research, such as the development of radar, primarily during World War II, that opened up many new areas of basic research. So it appears increasingly that the terms "basic" and "applied" are oversimplified and often misleading labels for parts of a very complex whole.

I might also note that the distinction between applied and basic research is not necessarily a function of the institution in which the research is done. A good many industrial firms which have research laboratories, firms in which the managements are primarily interested in applications leading to technology development, have found it very profitable to do basic research and in general do not find the distinction between basic and applied research useful in managing their laboratories.

We also see many examples of university research investigators whose primary interests may be in doing basic work—we see them turning to very practical and economically important tasks when circumstances are conducive.

If one begins rethinking the utility or lack of utility of distinguishing basic and applied research, it also soon becomes apparent that some of the clearcut lines we have been accustomed to drawing between science and the frontiers of engineering are also rather blurred.

Engineering was born as a practical and intuitive art, but that was some centuries ago, and today it embraces a range of knowledge from the highly theoretical to the very practical. It builds linkages on the one side with the physical, life, social sciences, and industrial practice on the other.

In engineering research, those engineers who devote their lives to creating the engineering of the future are as concerned with the discovery of new knowledge as with the application of knowledge already attained. And they perform research across the span from basic to applied, a span which is every bit as broad as that in other disciplines. We therefore are establishing an engineering directorate which will be comparable in its range of activities and in its organizational status to our other research directorates.

The Foundation's mandate to support research in all the sciences and engineering is a rather broad one, but we, in fact, provide only a small part of the total resources provided by the Federal Government in support of research in this country. That leads us to a resource allocation strategy which is based not on specific well-defined missions but on some general principles which relate to the support of basic research and to the health of science and engineering.

We think of these principles as four: First, as a rule, the research the Foundation supports is proposed by the investigator who will perform it. Thus, we believe opportunities to uncover new knowledge and new applications of knowledge are identified and pursued by those best placed to do so.

Second, the Foundation supports research with potential for making significant contributions to our knowledge base. These contributions are hence of broad potential applicability.

Third, we attempt to assure both quality and objectivity by basing our selection process on independent technical review by peers.

And fourth, we insist that the results of the research we support be widely and expeditiously disseminated through the open technical literature. These principles and the Foundation's broad legislatively defined responsibility for the vitality of American research underlie this recent organizational realinement.

These four principles still leave open the question of what emphasis ought to be given by NSF to different areas of research and of education. There are a great many claimants for our limited resources and many views of what we should emphasize.

Our proposals and plans for fiscal year 1982 include the maintenance of a strong base of support for research across the full range of science and engineering and they continue support for a wide range of science and engineering education programs. They also contain some new thrusts which we believe warrant the attention of the Congress. You have before you the detailed budget proposals and I would like to describe briefly some of these major thrusts.

First, there is one that I would refer to as technological innovation in the mathematical and physical sciences.

It is clear to all of us that there is a great deal of concern developing recently about the pace of technological innovation in this country, concern about the seeming ability of foreign competitors to swamp our American industry in the innovative manufacture and marketing of consumer electronic products. This concern is beginning to appear not only in what one might call the medium technology aspects of our industry, but also in the high technology aspects of our industry.

Much of the research that goes into the creation of new products and production techniques is the proper responsibility of private industry, of course. Private industry spends large amounts mainly for relatively focused applied research and for product development. IBM Corp., for example, spent in 1979 more than $1⅓ billion on R. & D. That is more than the entire NSF budget.

But underlying these very large expenditures by industry is broadly ranging research of the most fundamental nature in all the mathematical and physical sciences. The time scale for application of this research is often rather long, generally longer than that of research supported in industry, and it is often harder to foresee the ways in which that application will eventually be made.

But there is no doubt that that application will be made and there is no doubt that this most fundamental research can be applied on shorter time scales. Because of this, we are proposing substantial increases in all of the mathematical and physical sciences, with particular emphasis in mathematics and the computer sciences.

The second major thrust that I would like to describe is a thrust in engineering research. I have already noted that, in our view, it is incorrect to equate engineering research with applied research. Much of the work that concerns engineering researchers is directed at fundamental understanding to as great an extent as the work of fundamental researchers in other sciences.

In my written statement I note an example of this, the problem of fluid flow, in particular turbulent fluid flow. This is a problem which has been a major scientific and engineering problem for at least a century. It was addressed by Newton, by Rayleigh, and before that, even Leonardo da Vinci. But only recently, have some of the very interesting and potentially very important aspects of turbulent fluid flow begun to be understood. The advances in understanding have been made possible through work in pure mathematics, experimental work in schools of engineering, in departments of science, and advances in experimental techniques made possible by new instrumentation such as lasers.

As I have already noted, the Foundation is taking an important step to strengthen its engineering programs by establishing a directorate for engineering. We think this will focus on the intellectual development of engineering science. It will also have a subtle but rather important effect on the way we view and plan for the engineering disciplines, an effect in the long run that may be much more important than the specific budget increases proposed at this time.

We also recognize that our engineering research programs do need substantially increased resources in a number of areas, and providing these program increases will be a major part of our fiscal year 1982 effort.

A third major thrust in our plans for 1982 might be encompassed by the term "industrial science and technological innovation." That is a term which we have developed to label a new grouping of programs within our Directorate for Scientific, Technological, and International Affairs. It incorporates a number of activities aimed at strengthening the coupling between industry and university researchers and strengthening research in certain types of industries, in particular, small business.

This program includes our industry-university cooperative research program and our small business innovation program. The industry-university cooperative research program contributes funding to, and shares project funding with many of our other NSF programs. These are projects which come to us as proposals made jointly and cooperatively by researchers in both industry and universities. They must have passed the same quality review as others supported by the relevant disciplinary programs.

The small business innovation program supports research in small business; I emphasize research and not development. This research must be of both high scientific merit and it must also be of a type that appears likely, if it is successful, to attract substantial followon funding for the small business from some third-party source such as venture capital firms, large manufacturers, or other industrial sources.

Federal support that we provide thus acts as seed money, enabling small firms to undertake high quality but perhaps high risk research that will lead to future financing without Government involvement. Both of these programs, the industry-university cooperative research program and the small business innovation program, are relatively new; they appear to be very successful, and both are slated for substantial expansion in our plans for fiscal year 1982.

The fourth major thrust I would like to refer to is what we call the university research laboratories and instrumentation program. As we all know, modern science is increasingly dependent on sophisticated instruments that permit more precise measurements, allow development of new techniques, and open up new research opportunities. Yet a great deal of the research instrumentation and facilities in our Nation's universities, where the majority of our fundamental research is done, have become obsolescent. The research capability of our major research universities is eroding in comparison with our leading industrial laboratories and with our major foreign competitors.

This is a serious national problem of interest and concern not only to the universities but also to the industries which depend on a flow of well-trained new researchers and new knowledge coming out of the universities.

A program aimed at modernizing and upgrading university laboratories will permit research groups to be more productive and efficient and to undertake more advanced work, thus multiplying the return on investment of Federal research project support funds and also in some cases enabling university laboratories to meet modern standards for the handling of potentially dangerous biological, chemical, and radiological materials.

There has been no adequate sustained Federal investment in facilities of this type for at least a decade. The Foundation's plans for fiscal year 1982 call for initiating a major national effort to renew research instrumentation; selection criteria will emphasize likely increases in research productivity.

The last thrust I would like to mention has to do with education programs, specifically in engineering and computer science.

Last summer, the Secretary of Education and the Acting Director of the National Science Foundation submitted to the President a report which he had requested entitled "Science and Engineering Education for the 1980s and Beyond." That report reviewed the state of science, engineering, and mathematics instruction at all levels, and found it to be seriously deficient in several respects. Among the many significant problems noted in that report are a nationwide shortage of modern training facilities in engineering and computer science departments, and a major shortage of engineering faculty.

In response to these problems, the Foundation is proposing a substantial effort to provide up-to-date instructional equipment to departments of engineering and computer science at colleges and universities. We are, in addition, proposing a modest program of graduate traineeships in engineering and computer sciences intended to increase graduate enrollment and Ph. D. production in these fields, thereby helping to relieve severe faculty shortages in the future.

Mr. Chairman, the programs which the Foundation is proposing for fiscal year 1982, when considered together, make a good start, we think, toward remedying some of the major current deficiencies in American science and engineering research and education.

I have only touched on the most important of them in these brief remarks. We will have a good deal more to say about them in the hearings to come, and I hope my comments and those of Mr. Doan have given you some sense of our purpose. We would of course be happy to answer any questions which you or other members of the committee may have.

Thank you.

[The prepared statements of Dr. Langenberg and Mr. Doan follow:]

Statement of

DR. DONALD N. LANGENBERG
Acting Director, National Science Foundation
before the
Committee on Science and Technology
U.S. House of Representatives

January 28, 1981

Mr. Chairman, I am pleased to have this opportunity to appear before this Committee and present an overview of some salient features of the Foundation's proposed programs for Fiscal Year 1982. I regret that Dr. John B. Slaughter, who was sworn in last month as the new Director of NSF, is not able to be here today.

Mr. Chairman, this Committee has had a long association with the Foundation, and I need not review for you our fundamental missions and procedures in support of science and engineering research and education. But the unique mission of the Foundation to support research and to be concerned generally with the health of science across all disciplines may perhaps bear repeating and emphasizing. This is in contrast with the other agencies with substantial research efforts, for each of these agencies has a particular mission to perform, and must structure its research program accordingly.

The Foundation does it work primarily through grants to colleges, universities, and other researcher performers; it has no research laboratories of its own. It therefore has a relatively small staff, headed by Dr. Slaughter as Director, with overall policy set by the National Science Board. This Board is unique in government, composed as it is of distinguished academic and industrial scientists and administrators, who are appointed by the President to serve on a part time basis in determining the fundamental policies under which we operate. I am pleased to have beside me today Mr. Herbert D. Doan, Vice Chairman of the National Science Board. With your permission, I would like to ask him now to provide you with additional information concerning the Board's responsibilities.

Mr. Chairman, I would like to begin by discussing briefly our recent decisions on the internal organization of the Foundation, decisions which are reflected in the structure of the FY 1982 Budget proposal recently transmitted to the Congress. Last year when he appeared before this Committee, Dr. Richard C. Atkinson, former Director of NSF, noted that "There has been a remarkable drawing together of basic and applied research." This reflects the increasing frequency with which what we are used to calling "basic" research turns out to have applications, and the increasing extent to which social and economic problems are seen to have scientific or technological elements.

A few months after Dr. Atkinson made that statement, the National Science Board asked the staff to undertake a study of the organizational implications of charging each directorate of the Foundation with responsibility for supporting both basic and applied research within its disciplinary range. We began that effort last July, and by November we were convinced that we could more efficiently and more effectively carry out our legislatively-mandated responsibilities if we established an Directorate for Engineering in lieu of our existing Directorate for Engineering and Applied Science, and simultaneously assigned applied science responsibilities to what have been known as the "basic" research directorates.

Our study led us to the conclusion that the traditional distinction between "basic" and "applied" research is often forced and artificial. Virtually all good research is potentially applicable. We all recognize that it has been the source from which most modern technologies have developed. One need go back no farther than the discovery of DNA to find basic research that very quickly led to a technology of potentially enormous social and economic importance. One can equally readily think of examples of nominally applied research, such as the development of radar, that opened up many new areas of basic research. It increasingly appears that the terms "basic" and "applied" are oversimplified and sometimes misleading labels for parts of a very complex whole.

We can also see that the distinction between basic and applied research is not necessarily a function of the institutional setting in which research is done. Thus, many industrial research laboratories, where management is primarily interested in applications, have found it profitable to do very basic research, and do not find the distinction between basic and applied research useful. And we have also seen university-based investigators, with primary interests in doing basic work, turn to very practical and economically important tasks when circumstances are conducive.

When one begins rethinking the utility of distinguishing between basic and applied research, it also becomes apparent that some of the clear-cut lines we have been accustomed to draw between science and the frontiers of engineering also begin to blur. Although engineering was born as a practical and intuitive art, today it embraces a range of knowledge from the highly theoretical to the very practical. Engineering builds linkages with the physical, social and life sciences on one side, and with industrial practice on the other. Those engineers who devote their lives to creating the engineering of the future are as concerned with the discovery of new knowledge as with the application of knowledge already attained. For this reason, we believe it is wrong to think of engineering research as applied research or vice versa. We therefore intend to establish an engineering directorate that will be comparable in its range of activities to the other research directorates.

To say that the line between basic and applied research is indistinct, however, is not to deny important differences between types of research. The Foundation's mandate to support research in all the sciences and engineering is a broad one, but we provide only a small part of the total resources made available by the Federal government to research. This leads us to a resource allocation strategy based not to specific well-defined missions but on general principles relating to the support of basic research and the health of science and engineering:

1. As a rule, the Foundation supports research proposed by the investigator. Thus, opportunities to uncover new knowledge and new applications of knowledge are identified and pursued by those best placed to do so.

2. The Foundation supports research with potential for making significant contributions to our knowledge base and hence of broad potential applicability.

3. The Foundation attempts to assure both quality and objectivity by basing our selection process on independent technical review by peers.

4. The Foundation insists that the results of the research we support be widely disseminated through the open technical literature.

These principles, together with the Foundation's broad legislatively defined responsibility for the vitality of American research, underlie our recent organizational realignment. The research the Foundation supports and the purposes served by the results of that research are diverse and wide-ranging; they encompass enlarging man's view of the cosmos and enhancing the comfort and convenience of his life.

These four principles still leave open the emphasis to be given by NSF to different areas of research and education. There are many claimants for our limited resources and many views of what we should emphasize. Our proposals for FY 1982 include the maintenance of a strong base of support for research across the full range of science and engineering, and they continue support for a wide range of science and engineering education programs. They also contain some new thrusts which we believe warrant the attention of the Congress. Since you have before you the detailed budget proposals, I will simply describe briefly some of our major thrusts.

Technological Innovation and the Mathematical & Physical Sciences

In recent years we have all become concerned with the pace of technological innovation and the seeming ability of foreign industry to swamp our American competitors in the innovative manufacture and marketing of consumer electronic products. I am thinking of television and stereo equipment, self-focusing cameras, home video recorders, and other precision products. As Dr. Philip Abelson, the editor of Science, observed editorially a few weeks ago, the Japanese are also mounting a vigorous challenge in areas in which the American lead at one time had seemed unassailable -- computers, communications, semiconductor microcircuits, robotics and others. In the span of only three years, Japanese companies have taken over 40 percent of the world market for 16,000-bit random access memory chips, a key component of modern computers. Hewlett-Packard Co., one of the three largest users of these chips in the United States, reports that the Japanese devices are superior in several respects to those from American sources. There are fewer failures during inspection, production, and use by customers, and therefore, warranty costs are lower.

Much of the research that goes into the creation of new products and production techniques, of course, is the proper responsibility of private industry, which spends very large amounts, mainly for relatively focused applied research and for product development. IBM, for example, spent more than $1.36 billion on R&D in 1979, more than the entire NSF budget. But underlying these very large expenditures is broadly ranging research of the most fundamental nature in all the mathematical and physical sciences. The time scale for application of this research is generally longer than that of research supported in industry, and it is generally harder to foresee the ways in which that application will be made. But there is no doubt that the application will be made. There is no doubt that, in general, it is research of this most fundamental sort, in the sense that it is aimed at better understanding of the most fundamental physical processes, that makes possible research in industry that can be applied on shorter time scales. We are thus proposing substantial increases in all the mathematical and physical sciences, with particular emphasis in mathematics and computer science.

Engineering Research

I have already noted that it is incorrect to equate "engineering" and "applied research." Much of the work that concerns engineering researchers is directed at fundamental understanding to as great an extent as the work of fundamental researchers in other sciences.

As an example of what I mean, consider the problem of turbulent fluid flow. This is a phenomenon associated with bodies moving through a viscous fluid medium, as well as for fluids moving through pipes, pumps, turbines, and the like. Designers of a tremendous variety of equipment want to assure a smooth flow in so far as possible. Once the flow separates from hulls, airfoils or ducts, drag or resistance rises abruptly and the efficiency of the system decays sharply. Some of the greatest scientific minds in history have wrestled with the problem, including Da Vinci, Newton, and Rayleigh. The conventional wisdom gained from this prolonged effort has been that flow separation means unpredictable chaos in the flow. However, recent advances in pure mathematics and in experimental techniques suggest that the onset of turbulence may actually involve a pulsating structure or repetitive pattern, something more tractable to mathematical analysis than anyone had thought. This research is still quite preliminary, but may have a great impact on the design of aircraft and ships, and the design of efficient mixing and heat exchange systems such as rocket engine combustors and steam condensers.

As I have already noted, the Foundation is taking an important step to strengthen its engineering programs by establishing a Directorate for Engineering. This will help us focus on the development of the intellectual foundations of engineering science. It will also have a subtle but important effect on the way we view and plan for the engineering disciplines -- an effect that will be much more important in the long run than the specific budget increases proposed at this time. But we also recognize that our engineering research programs need substantially increased resources in a number of areas. Providing these program increases will be a major part of our FY 1982 effort.

Industrial Science and Technological Innovation

Over the last three years, the Foundation has experimented with several programs to stimulate linkages between researchers in industry and in academic institutions. As part of the reorganization now taking place, the Foundation is grouping these programs together into a new budget subactivity entitled

Industrial Science and Technological Innovation. This subactivity includes our Industry-University Cooperative Research Program and our Small Business Innovation program. The Industry-University program shares funding of individual projects with many other NSF programs. These projects are performed cooperatively by researchers in industry and universities, and have passed the same quality review as others supported by those programs. The Small Business Innovation program supports research in small business which is both of high scientific merit and appears likely to attract substantial follow-on funding by a third party source such as venture capital firms, large manufacturers, or other industrial sources; Federal support thus acts as seed money, enabling small firms to undertake high quality research that will lead to future financing without Government involvement. Both programs appear to be very successful and both are slated for substantial expansion in our plans for FY 1982.

University Research Laboratories and Instrumentation

Modern science is increasingly dependent on sophisticated instruments that permit more precise measurements, allow development of new techniques, and open up research opportunities. Yet much of the research instrumentation and facilities of our Nation's universities, where the majority of our fundamental research is done, have become obsolescent. The research capability of our major universities is eroding in comparison with our leading industrial laboratories and with our major foreign competitors. This is a serious national problem, one of concern not only to the universities but to the industries which depend on a flow of well trained new researchers and new knowledge.

Modernizing and upgrading university laboratories will permit research groups to be more productive and efficient and to undertake more advanced work, thus multiplying the return on investment of Federal research project support funds Improvement will also enable such laboratories to meet modern standards for handling of potentially dangerous biological, radiological, and chemical materials.

There has been no adequate sustained Federal investment in facilities of this type for at least a decade. The Foundation's plans for FY 1982 call for initiating a major national effort to renew research instrumentation in our research universities. The program is aimed at strong research groups requiring advanced state-of-the-art instrumentation to reach their full potential, and selection criteria will emphasize likely increases in research productivity.

Education Programs in Engineering and Computer Science

"Science and Engineering Education for the 1980's and Beyond," the 1980 report to the President prepared by the

Foundation and the Department of Education, reviewed the state of U.S. science, engineering and mathematics instruction, and found it seriously deficient in several respects. Among the many significant problems noted in the report are a nationwide shortage of modern training facilities in engineering and computer science departments and a shortage of engineering faculty. To respond to these problems, the Foundation is proposing a substantial effort to provide up-to-date instructional equipment to departments of engineering and computer sciences at colleges and universities of all types. In addition, we propose a modest program of graduate traineeships in engineering and computer sciences, to increase graduate enrollment and Ph.D. production in these fields and thereby help relieve severe faculty shortages.

Mr. Chairman, the programs which the Foundation is proposing for FY 1982, when considered together, make a good start towards remedying some of the major current deficiencies in American science and engineering. I have only touched on the most important of them in these brief remarks, but we will have much more to say in the hearings to come. I hope my comments have been enough to give you a sense of our purpose, however. I will of course be happy to try to answer any questions you or other members of the Committee may have.

Thank you.

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STATEMENT OF MR. HERBERT D. DOAN
VICE CHAIRMAN, NATIONAL SCIENCE BOARD
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES
JANUARY 28, 1981

MR. CHAIRMAN, MEMBERS OF THE COMMITTEE:

IT IS A PLEASURE FOR ME TO BE PRESENT TODAY IN SUPPORT OF THE NATIONAL SCIENCE FOUNDATION (NSF). DR. LEWIS M. BRANSCOMB, CHAIRMAN, NATIONAL SCIENCE BOARD, HAS ASKED ME TO OFFER HIS REGRETS AT NOT BEING ABLE TO MEET WITH YOU DUE TO A PREVIOUS ENGAGEMENT.

I HAVE BEEN PRIVILEGED TO SERVE AS A MEMBER OF THE NATIONAL SCIENCE BOARD SINCE 1976. IN 1979 MY COLLEAGUES ELECTED ME TO THE BOARD'S EXECUTIVE COMMITTEE AND IN 1980 TO BE THE BOARD'S VICE CHAIRMAN.

THE ROLE OF THE NATIONAL SCIENCE BOARD

FOR THE BENEFIT OF THE NEW MEMBERS OF THIS COMMITTEE, I WOULD LIKE TO MAKE A FEW BRIEF REMARKS ABOUT THE ROLE OF THE NATIONAL SCIENCE BOARD.

THE NSF ACT OF 1950, AS AMENDED, STATES THAT "THE FOUNDATION SHALL CONSIST OF A NATIONAL SCIENCE BOARD...AND A DIRECTOR." THIS ENABLING LEGISLATION ASSIGNS POLICYMAKING FUNCTIONS TO THE NATIONAL SCIENCE BOARD AND THE ADMINISTRATION OF THE FOUNDATION TO THE DIRECTOR, WITHIN THE OVERALL POLICY FRAMEWORK SET FORTH BY THE CONGRESS AND THE PRESIDENT.

THE NATIONAL SCIENCE FOUNDATION IS THE ONLY FEDERAL BODY WHICH HAS AS ITS BROAD CHARTER RESPONSIBILITY FOR THE OVERALL HEALTH OF FUNDAMENTAL SCIENCE IN THE UNITED STATES. THE POLICIES ESTABLISHED BY THE BOARD ON THE SUPPORT OF SCIENCE AND ENGINEERING AND THE

DEVELOPMENT OF SCIENTIFIC MANPOWER ARE IMPLEMENTED THROUGH THE PROGRAMS OF THE FOUNDATION. THE BOARD ALSO ASSISTS IN THE FORMULATION OF MAJOR NATIONAL SCIENCE POLICIES, PARTICULARLY AS THEY RELATE TO THE GENERAL STATE OF SCIENCE IN THE NATION. IT INITIATES STUDIES TO IDENTIFY PROMISING AREAS OF RESEARCH TO ADD TO THE FUND OF KNOWLEDGE, TO IMPROVE THE QUALITY OF LIFE, AND TO ASSIST IN THE SOLUTION OF NATIONAL SOCIETAL PROBLEMS. THROUGH ITS ANNUALLY MANDATED REPORTS TO THE CONGRESS, THE BOARD ASSESSES AND REPORTS ON THE STATUS AND HEALTH OF SCIENCE.

THE NATIONAL SCIENCE BOARD INCLUDES TWENTY-FOUR PART-TIME MEMBERS, APPOINTED BY THE PRESIDENT WITH THE ADVICE AND CONSENT OF THE SENATE, AND THE DIRECTOR OF THE FOUNDATION *EX OFFICIO*. AS SPECIFIED IN THE ACT, RECOMMENDATIONS FOR MEMBERSHIP ARE SOUGHT, ON BEHALF OF THE PRESIDENT, FROM THE MAJOR SCIENTIFIC, ENGINEERING, AND EDUCATIONAL SOCIETIES AND ASSOCIATIONS. ALL RECOMMENDATIONS RECEIVED FROM ALL SOURCES ARE FORWARDED TO THE WHITE HOUSE FOR CONSIDERATION TOGETHER WITH THE JOINT RECOMMENDATIONS OF THE BOARD AND DIRECTOR.

IN FORMULATING ITS RECOMMENDATIONS FOR MEMBERSHIP, THE BOARD CONSIDERS THOSE FACTORS STATED IN SECTION 4(C) OF THE NSF ORGANIC ACT. PROFESSIONAL QUALIFICATIONS ARE THE PRIMARY CONSIDERATION, AS WELL AS PUBLIC SERVICE, GEOGRAPHICAL DISTRIBUTION, AND BALANCE AMONG PROFESSIONAL FIELDS (INCLUDING SCIENCE EDUCATION, LAW, AND PUBLIC AFFAIRS). ALSO WEIGHED ARE MANAGEMENT CAPABILITY, REPRESENTATION OF WOMEN AND MINORITY GROUPS, AND REPRESENTATION OF VARIOUS TYPES AND SIZES OF EDUCATIONAL AND RESEARCH ORGANIZATIONS AND INDUSTRY.

The Board is thus constituted of a wide diversity of people interested in science, with a broad breadth of backgrounds and differences in opinion. Nine past NSB Members have been from predominantly undergraduate institutions. Eight present NSB Members are from nonacademic institutions. Four, Dr. Raymond L. Bisplinghoff, Dr. Lewis M. Branscomb, Dr. Mary L. Good, and I, are industrial executives.

The term of office of Members is six years, expiring on May 10 of the even years. Thus, terms of eight Members will expire on May 10, 1982. The current membership of the Board is shown in Appendix I.

The Board meets about nine times a year, usually for three days at a time. Its policymaking responsibilities are met in a number of ways, largely through its committees (listed in Appendix II). It is extensively involved in long-range planning, the determination of priorities, budgeting, and the development of new programs. The process begins with identification by the Board and staff of longer term concerns which may affect many fields of science. Background information on these issues and on the anticipated future environment is prepared by NSF staff. At its June planning environment review, held under the aegis of its Planning and Policy Committee, the Board discusses such topics, formulates recommendations, and considers possible actions.

Subsequently, the Board examines the scientific and program priorities of the Foundation's long-range plans and provides guidance, through its Budget Committee, in the preparation of multiyear cost estimates. As the Director develops the

Foundation's budget submission to the President, the Board is consulted.

Status of Science Reviews--1981, developed by the Board and the Foundation staff, is a document which provides background for the Board in its planning and budgeting activities. It may also be of interest to the Congress and others considering the future of the scientific and engineering enterprise. This report is the latest of a series summarizing the judgments of the individual NSF program directors about the current directions and opportunities in the fields of science and engineering supported through each directorate. Continuing attention is given to describing the role of the Foundation vis-a-vis other sources of support for research and science education in the Nation. A copy will be provided for the record.

Oversight by the National Science Board

Oversight of the activities of the Foundation is a major NSB responsibility. It is carried out by individual Members' activities, through the Programs Committee, as well as through the Audit and Oversight Committee.

Other means by which the Board discharges its oversight responsibilities include receipt of program reviews at NSB meetings, participation by the Members in site visits to the National Centers and other NSF-supported facilities and activities, and attendance at and reporting upon meetings of the NSF Advisory Council and other Foundation advisory committees.

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NATIONAL SCIENCE FOUNDATION PROGRAM FOR FISCAL YEAR 1982

AS INDICATED ABOVE, THE NATIONAL SCIENCE BOARD HAS HAD A MAJOR ROLE IN THE DEVELOPMENT OF THE FOUNDATION'S PROGRAM FOR FISCAL YEAR 1982. IT EMPHASIZES THE INVESTMENT NATURE OF THE FOUNDATION'S RESEARCH AND EDUCATION PROGRAMS AND THE IMPORTANCE OF SCIENCE AND TECHNOLOGY TO THE NATION'S FUTURE. THE STRENGTH AND INTERNATIONAL COMPETITIVENESS OF THE COUNTRY'S SCIENTIFIC CAPABILITY MUST BE MAINTAINED, AND THE PROPOSED PROGRAM TAKES STEPS TO DO SO.

AMONG THE THRUSTS OF PARTICULAR INTEREST IN THE PROGRAM IS THE STRENGTHENING OF RESEARCH PROGRAMS, WITH AN EMPHASIS ON CERTAIN AREAS UNDERLYING INDUSTRIAL PRODUCTIVITY AND INNOVATION, ESPECIALLY IN THE PHYSICAL SCIENCES, ENGINEERING, COMPUTER SCIENCE, AND MATHEMATICS.

ANOTHER IMPORTANT FOCUS IS THE EFFORT TO UPGRADE UNIVERSITY RESEARCH LABORATORIES THROUGH A NEW PROGRAM TO REFURBISH OUTDATED FACILITIES. THIS MAJOR INVESTMENT IN U.S. SCIENTIFIC AND ENGINEERING RESEARCH CAPABILITY IS AS BADLY NEEDED, TO UPDATE FACILITIES RAPIDLY BECOMING OBSOLETE, AS IS THE COMPARABLE REQUIREMENT FOR PROMOTING HIGH TECHNOLOGY BUSINESS GROWTH AND MODERNIZING INDUSTRIAL PLANTS.

THE BOARD SEES BOTH THESE OBJECTIVES SERVED BY THE INVESTMENT PROPOSED. A MAJOR INVESTMENT IN RESEARCH INSTRUMENTATION WILL EXERT A CAPABILITY-STRETCHING DEMAND ON THE INSTRUMENT INDUSTRY, WITH A STIMULATING EFFECT ON THAT INDUSTRY. ADVANCED INSTRUMENTATION IS NOT ONLY THE MEANS WHEREBY THEORETICAL SCIENCE IS TESTED AND QUANTIFIED, IT IS OFTEN THE LINK BETWEEN EXPERIMENTAL SCIENCE AND THE INDUSTRIAL PROCESS, FOR TODAY'S MEASURING INSTRUMENT IS

TOMORROW'S FABRICATION TOOL. IT IS IMPORTANT FOR NSF TO HAVE A MAJOR INCREMENT NOW, BUT OTHER AGENCIES SHOULD UNDERTAKE THEIR SHARE OF THIS INVESTMENT AS WELL.

ANOTHER IMPORTANT FOCUS IS ON THE URGENT NEED TO UPGRADE THE SCIENCE AND ENGINEERING INSTRUCTIONAL AND RESEARCH CAPABILITY FROM WHICH PRIVATE INDUSTRY DRAWS ITS PEOPLE AND IDEAS AND ON WHICH IT MOST STRONGLY DEPENDS. AMERICA'S ENGINEERING SCHOOLS PARTICULARLY NEED FAST AND WELL-FOCUSED UPGRADING THROUGH:

-- INSTRUCTIONAL EQUIPMENT TO ENSURE THAT GRADUATES ARE READY TO PRACTICE THE MOST ECONOMICALLY EFFICIENT TECHNOLOGIES FOR DEVELOPMENT AND PRODUCTION.

-- TRAINEESHIPS TO ENCOURAGE RETENTION OF GRADUATE STUDENTS TO THE DOCTORATE SO THAT THE NEXT GENERATION OF FACULTY CAN BE TRAINED, ESPECIALLY IN SHORTAGE FIELDS LIKE COMPUTER SCIENCE AND SEVERAL FIELDS OF ENGINEERING.

-- ENGINEERING SCHOOLS WILL ALSO BENEFIT FROM THE FOUNDATION'S GENERAL ENCOURAGEMENT OF UNIVERSITY-INDUSTRY RESEARCH COOPERATION IN SEVERAL FORMS, BOTH FOR THE BADLY NEEDED KNOWLEDGE AND FOR THE SHARING OF SCIENTIFIC AND INDUSTRIAL INSIGHTS BY RESEARCHERS, FACULTY, AND STUDENTS.

IN ADDITION TO THE ABOVE MAJOR AREAS OF INVESTMENT, BOARD MEMBERS FEEL THAT ADDITIONAL EMPHASIS NEEDS TO BE GIVEN TO THE QUALITY OF SCIENCE AND MATHEMATICS INSTRUCTION AND THE CAREER MOTIVATION OF SECONDARY SCHOOL STUDENTS AND CONTINUED ATTENTION TO REMOVING DISADVANTAGES SUFFERED BY WOMEN AND MINORITIES WHO WISH TO PARTICIPATE IN THE GROWING OPPORTUNITIES IN SCIENCE AND engineering. Competent people must be drawn from the largest possible cadre available in the Nation.

A major expansion is also needed in materials research with special emphasis on engineering materials, such as polymers, ceramics, metallurgy, composites, and adhesives. This area, underdeveloped by NSF, parallels the more science-oriented Materials Research Laboratory Program and is probably the single most broadly useful research for industry the Government could support.

The Foundation's industry/university cooperative research efforts, intended to stimulate the research programs of both industry and universities, should be markedly increased. These activities are proving successful in encouraging industrial and academic scientists and engineers to work jointly on exciting research problems at the forefront of knowledge.

Finally, another special emphasis, the Ocean Margin Drilling Program (OMD), is a logical extension of the highly successful Deep Sea Drilling Project. It is an attractive convergence of scientific goals, resource exploration, and technological development, and involves the U.S. petroleum industry. The National Science Board is following closely the development of this program and believes that ~~it can~~ be of great scientific importance. In addition, the OMD Program will aid in the development and application of deep water technology and will be an important step in the geological understanding of the continental margins. OMD offers new opportunities for extensive and profitable collaboration among NSF, other Federal agencies, industry, and foreign countries.

The Board strongly supports the National Science Foundation's proposed program for fiscal year 1982. It welcomes the new initiatives proposed for the Foundation as an expression of confidence in science and in the Foundation and its approaches to the Nation's problems.

The National Science Board urges continued support of basic research, programs to improve linkages between universities and industry and small business, upgrading of research instrumentation, and science education. These are important elements of a national strategy to restore the Nation's economic vitality and maintain our scientific and technological leadership during the coming decade.

In closing, Mr. Chairman, I would like to express my appreciation to you and the Members of this Committee for your understanding and support of science and technology and the National Science Foundation.

APPENDIX I

January 2, 1981

NATIONAL SCIENCE BOARD

Terms Expire May 10, 1982

DR. RAYMOND L. BISPLINGHOFF, Vice President for Research and Development, Tyco Laboratories, Inc., Tyco Park, Exeter, New Hampshire 03833

*DR. LLOYD M. COOKE, Vice Chairman, Economic Development Council of New York City, Inc., 200 Madison Avenue, New York, New York 10016

*MR. HERBERT D. DOAN, (Vice Chairman, National Science Board), Chairman, Doan Resources Corporation, 110 East Grove Street, Midland, Michigan 48640

DR. JOHN R. HOGNESS, President, Association of Academic Health Centers, 11 Dupont Circle, N.W., Suite 210, Washington, D. C. 20036

DR. WILLIAM F. HUEG, JR., Professor of Agronomy and Deputy Vice President and Dean, Institute of Agriculture, Forestry, and Home Economics, 201 Coffey Hall, University of Minnesota, St. Paul, Minnesota 55108

*DR. MARIAN E. KOSHLAND, Professor of Bacteriology and Immunology, Department of Bacteriology and Immunology, University of California at Berkeley, Berkeley, California 94720

DR. JOSEPH M. PETTIT, President, Georgia Institute of Technology, Atlanta, Georgia 30332

DR. ALEXANDER RICH, Sedgwick Professor of Biophysics, Department of Biology, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

Terms Expire May 10, 1984

*DR. LEWIS M. BRANSCOMB (Chairman, National Science Board), Vice President and Chief Scientist, International Business Machines, Inc., Armonk, New York 10504

DR. EUGENE H. COTA-ROBLES, Professor of Biology, Biology Board of Studies, 259C Applied Science Building, University of California at Santa Cruz, Santa Cruz, California 95064

DR. ERNESTINE FRIEDL, Dean of Arts and Sciences and Trinity College, and Professor of Anthropology, 216 Allen Building, Duke University, Durham, North Carolina 27706

DR. MICHAEL KASHA, Distinguished Professor of Physical Chemistry, Institute of Molecular Biophysics, Florida State University, Tallahassee, Florida 32306

DR. WALTER E. MASSEY, Director, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

DR. DAVID V. RAGONE, President, Case Western Reserve University, University Circle, Cleveland, Ohio 44106

DR. EDWIN E. SALPETER, J. G. White Professor of Physical Sciences, 308 Newman Laboratory of Nuclear Studies, Cornell University, Ithaca, New York 14853

DR. CHARLES P. SLICHTER, Professor of Physics and in the Center for Advanced Study, 311 Loomis Laboratory of Physics, University of Illinois, Urbana, Illinois 61801

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*Member, Executive Committee

Terms Expire May 10, 1986

DR. PETER T. FLAWN, President, University of Texas at Austin, P. O. Drawer T, Austin, Texas 78712

DR. MARY L. GOOD, Vice President, Director of Research, United Oil Products, Inc., Corporate Research Center, Ten UOP Plaza, Algonquin and Mt. Prospect Roads, Des Plaines, Illinois 60016

DR. PETER D. LAX, Professor of Mathematics, Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York, New York 10012

**DR. HOMER A. NEAL, Dean of Research and Graduate Development, and Professor of Physics, Bryan 104, Indiana University,-Bloomington, Indiana 47405

DR. MARY JANE OSBORN, Professor and Head, Department of Microbiology, University of Connecticut School of Medicine, Farmington, Connecticut 06032

DR. DONALD B. RICE, JR., President, The Rand Corporation, 1700 Main Street, Santa Monica, California 90406

DR. STUART A. RICE, Frank P. Hixon Distinguished Service Professor of Chemistry, The James Franck Institute, University of Chicago, 5640 South Ellis Avenue, Chicago, Illinois 60637

(One Vacancy)

Member Ex Officio

*DR. JOHN B. SLAUGHTER (Chairman, Executive Committee), Director, National Science Foundation, Washington, D.C. 20550

* * *

MISS VERNICE ANDERSON, Executive Secretary,
National Science Board, National Science
Foundation, Washington, D. C. 20550

**On sabbatical at Stanford University. Mail should be sent to 924 Siskiyou Drive, Menlo Park, California 94025.

APPENDIX II

January 1981

NATIONAL SCIENCE BOARD

COMMITTEE STRUCTURE AND MEMBERSHIP

The National Science Foundation Act assigns policymaking functions to the National Science Board and the administration of the Foundation to the Director. The Board's policymaking responsibilities are met initially through the work of its committees.

Except for the Executive Committee, which is a statutory committee, the National Science Board and its Chairman establish the committees of the Board and make appointments to them. At each annual meeting the Board reviews the committee structure and the continuation of the task and ad hoc committees.

Board committees fall into four categories: statutory, standing, task, and ad hoc. The functions of the committees consist of a series of initial charges and such variations as are deemed desirable and useful once the committees are in operation.

The functions and chairmanship of the current Board committees are given below:

A. STATUTORY COMMITTEE

Section 7(a) of the National Science Foundation Act, as amended, states that:

> There shall be an Executive Committee of the Board (referred to in this Act as the "Executive Committee"), which shall be composed of five members and shall exercise such powers and functions as may be delegated to it by the Board. Four of the members shall be elected as provided in subsection (b), and the Director ex officio shall be the fifth member and the chairman of the Executive Committee.

The Executive Committee has the following responsibilities:

- Fulfills statutory functions: (1) exercises such powers and functions as may be delegated to it by the Board, and (2) renders an annual report to the Board, and such other reports as it may deem necessary, summarizing its activities and making such recommendations as it may deem appropriate. Minority views and recommendations, if any, of members of the Executive Committee are included in such reports.
- Acts on behalf of the Board between meetings on (1) grants, contracts, or other arrangements; and (2) other instances where immediate decision is required. (All such actions are reported to the Board at its next meeting.)

- Coordinates and offers guidance on activities of the Board and its committees.

- Serves as agenda committee for the Board.

- Identifies subjects to be considered by task and ad hoc committees.

- Considers and approves affiliations of the Director, Deputy Director, and Assistant Directors.

B. STANDING COMMITTEES

The standing committees of the Board are continuing committees with definite responsibilities to perform assigned tasks and to present recommendations to the Board. All Members who are not on the Executive Committee are assigned to either the the Planning and Policy Committee or the Programs Committee.

1. The Audit and Oversight Committee, chaired by Dr. Lloyd M. Cooke, reviews the requirements for continued functioning of the Action Review Boards and the effectiveness of other oversight mechanisms.

2. The Budget Committee, chaired by Dr. Marian E. Koshland:

   - Provides a focal point for Board participation in budgetary matters, including program priorities.

   - Provides advice to the Board on NSF authorization and appropriation issues.

   - Reexamines priority considerations, based on results of the long-range planning meetings, to integrate (a) immediate priorities into summer and fall budget preparation, and (b) deferred program priorities into fall preparation of long-range planning estimates.

   - Meets with Planning and Policy Committee to review results of Board discussion of and actions/guidelines on the planning environment review document for long-range planning meetings.

   - Helps serve as spokesman for the Board on NSF budgetary matters with the Congress and the Office of Management and Budget.

3. The Planning and Policy Committee, chaired by Dr. Walter E. Massey:

   - Considers policy issues and prepares draft documents including "white papers" on principal planning and policy issues affecting research and science education for subsequent Board consideration.

- Identifies and recommends actions for the Board with regard to policies and practices affecting research and science education in the Nation with particular attention to NSF.

- Develops and coordinates the long-range planning meetings of the Board and all associated documentation through interaction with NSF staff.

- Identifies national science policy issues and national needs and considers the proper roles of the Federal Government in general and NSF in particular.

- Meets with the Budget Committee to coordinate planning, policy, and budget processes.

The Planning and Policy Committee has four active subcommittees:

- Coordination and Management of Applied Research, chaired by Dr. Joseph M. Pettit;

- NSB and National Science and Technology Issues, chaired by Dr. Raymond L. Bisplinghoff;

- Science Education, chaired by Dr. John R. Hogness;

- Science and Society, chaired by Dr. Eugene H. Cota-Robles.

4. The Programs Committee, chaired by Dr. Ernestine Friedl:

   - Reviews proposed programs and makes recommendations to the Board.

   - Reviews all proposals for support containing new policy issues or over certain dollar amounts prior to presentation to the Board with Committee recommendations.

   - Monitors existing programs and activities.

   - Maintains oversight on long-term commitments of the Foundation.

   - Schedules formal and informal reviews of programs, especially for input to discussion of the planning environment review document at the long-range planning meetings.

C. TASK COMMITTEES

The task committees of the Board are assigned specified tasks which are sometimes of a short-term nature. These committees are discharged upon completion of these assigned tasks.

1. The Committee on Minorities and Women in Science, chaired by Dr. Eugene H. Cota-Robles, considers education and research programs to increase the flow into science of (a) ethnic minorities, (b) women, (c) the disadvantaged, and (d) the physically handicapped.

2. The Committee on Twelfth NSB Report, chaired by Dr. John R. Hogness, provides oversight on preparation of the report to the President and the Congress. The Report deals with the rich variety of mutual interplay between scientific research, the development of technologies, and social utility.

3. The Committee on Thirteenth NSB Report, chaired by Dr. Joseph M. Pettit, provides oversight on preparation of *Science Indicators--1980*, due March 1981.

4. The Committee on Fourteenth NSB Report, chaired by Mr. Herbert D. Doan, provides oversight on preparation of the report to the President and the Congress, due March 1982. This Report addresses the practices, problems, and potentials of university-industry research relationships in the U.S.

D. AD HOC COMMITTEES

Ad Hoc Committees of the Board have specific tasks generally of short duration.

1. Ad Hoc Committee on Deep Sea and Ocean Margin Drilling Programs, chaired by Dr. Raymond L. Bisplinghoff, monitors the developments regarding the future drilling programs and advises the Board of the alternatives that are being considered, the management of the programs, the costs, and how those costs might be shared among agencies of the U.S. Government, industry, foreign countries, or other groups.

2. Ad Hoc Committee on NSB and NSF Staff Nominees, chaired by Dr. William F. Hueg, Jr., offers recommendations to the Board on candidates for the vacancy on the Board and the position of Assistant Director for Science Education.

Mr. FUQUA. Thank you very much, Dr. Langenberg and Dr. Doan. We appreciate your being here and are thankful for your statement.

I would just like to say that probably nobody has been a stronger supporter of the National Science Foundation than I, or maybe at times has been as critical of the National Science Foundation, but I want to say I think what you have outlined in your proposed budget request not only reflects the concerns that we have had on this committee for the last few years, but I think it is an indication that you are responding to the needs that Congress and the American people have been expressing related to trying to bring this country back around in productivity and innovation.

I specifically point out the program for traineeships in our colleges and universities, particularly engineering and computer science, which I think is absolutely essential. We recognized that last year and supported funds for other budgets and encouraged NSF to get back into that program that had been neglected for some time.

Also, in the recognition of engineering, your reorganization I think reflects its importance. The program for research laboratories and improved instrumentation, I think, are all very, very worthwhile additions and directions that the budget is taking. I want to commend you for it.

I certainly hope that the committee and the Congress in its wisdom will see fit to follow the leadership that you have given in recognizing that and following through. If this country is to try to get at some of the root causes of our problems—you have addressed them in this statement and I want to commend you very much for that.

Dr. LANGENBERG. Thank you very much.

Mr. FUQUA. I think it is very important. I can assure you of my help in trying to make sure these programs are funded, because they are very essential to the mission of your agency and also to the overall national will and well being. So I want to commend you for that. I am sure we will go into more detail later in the budget requests that you have as we start our hearings later on next month.

But I do want to commend you. I think that the foundation has responded to very critical needs. If we neglect the life-blood of research in this country—and that is training scientists—then we are ignoring some of the real causes that we have. It is time we recognize that and I am glad to see the Foundation recognize that. I will save my questions for later maybe.

Mr. Winn?

Mr. WINN. Thank you, Mr. Chairman. I want to add my comments to yours and agree with what you have just said.

I would like to talk a little bit about budget. In the appropriations for 1981 you posed a 2-percent cut in the budget for a group of agencies including NSF. Now, someone decides to take NSF's share of the cut all out of science education. Now, for 1982 the NSF budget strongly emphasizes science and engineering education. I wonder could you explain this apparent reversal in the priorities?

Mr. LANGENBERG. The net result of all of the considerations and activities concerning the 1981 budget did nonetheless leave science education at approximately $5 million above the administration request. It also left the research and related activities portion of the budget about an equal amount below the administration request.

Having said that, I will say that I, personally, and I think many of us in the Foundation were somewhat disappointed to find the final administration decision falling most heavily on science education.

On the positive side, in a situation where the potential cut from the Foundation budget as a whole might have been as much as 3 percent across the board, we wound up with an overall cut of approximately two-tenths of 1 percent. We do take some comfort in that.

Our proposals and our plans that you will see in the budget for science and engineering education for 1982 reflect a strong concern for science and engineering education. We will have an opportunity to discuss those in more detail at the later hearings. But I would simply like to state that the Foundation does indeed take very seriously its responsibilities for science and engineering education as well as research. I might mention that the National Science Board, at the moment, is undertaking a rather intensive study of the Foundation's role in science and engineering education.

We expect that that study will continue throughout the spring and will lead to a full Board review of the Foundation's role in science and engineering education and of whether that role is being properly exercised.

Mr. WINN. Along that line, NSF controls only, according to my figures, 0.1 percent of the national expenditures on education. I wonder how can this relatively small program gain any kind of a real leverage which is needed to affect the massive problems?

Dr. LANGENBERG. I suppose the Foundation's role might most adequately be characterized as that of a catalyst in many of its programs. That is to say that the role, because of that relatively small budgetary contribution to the whole, must necessarily be that of an innovator, an encourager, a provider of information, of knowledge, of learning if you will, which can be applied to larger sources of resources. That is reflected in the kinds of things that the Science Education Directorate does.

Where it supports people it does so in two general areas—it provides support for students who will ultimately themselves become teachers, and researchers, and out of proportion to their absolute numbers, will have very significant effects upon the science and engineering research and education communities of the future.

We also have programs aimed at helping teachers, both at the university and secondary school levels, to stay abreast of developments in science and technology. Here again the application of relatively small amounts of resources can often help a teacher change the subjects taught in a way that can have a very large effect on large numbers of students.

We do perform research and development in education. Here again the aim is achieving large leverage toward improvements in educational systems by providing new knowledge which can be used by those in States, at the local level, in our universities, both public and private, to improve what they do in training both the general citizenry and scientists and engineers.

Mr. WINN. I notice one of the recommendations of the "Hufstedler-Langenberg Report on Science and Engineering Education for the 1980's and Beyond" was to urge industry to form voluntary associations for support of education and research, perhaps through the help and guidance of NSF and Department of Education.

I wonder if you can tell the committee, give us some ideas how industry might be induced or perhaps shown how to do just that?

Dr. LANGENBERG. I am not sure that our ideas at the Foundation—certainly my own ideas—are well formed on exactly how this might be done.

It is clear that industry also plays a very large role in the overall education enterprise of the country, largely for the moment through programs aimed at retraining, retooling, updating industry's own staffs, and to a lesser but nevertheless very important extent, in helping universities with their research and education programs through contributions, and exchanges of personnel.

But in talking to friends, colleagues from industry, I find they have become aware of the very serious deficiencies in at least two areas pointed out in that report: faculty retention in the engineering schools, and the entire issue of technological literacy in the primary and secondary school.

Talking to these people, I have sensed an interest in doing something about it. I can think of several examples of ways in which this might be done, and I am sure members of the committee and others here in the room can think of many more. Industry forms part of the communities in which it functions. Its science and engineering staffs, it seems to me, could band together and in informal ways or perhaps formal ways, assist the local schools, secondary schools, and universities, in providing instruction in particular fields where the industry scientists and engineers may have special expertise.

In the secondary schools there is, we believe, evidence of significant shortages of teachers adequately trained in mathematics and the sciences. There again, it seems to me, either by direct classroom teaching, by involving secondary school students in industrial settings on weekends, by carrying on informal, after-hour tutoring and courses, the industry scientists and engineers can make very important contributions.

Another set of ways I can think of might be focused on the engineering schools. Among the needs we have identified, and to which we are trying to respond in our 1982 plans, are the instructional equipment needs. As industry fully realizes, the students it is getting from the engineering schools have not been trained on equipment which allows the students to move quickly and efficiently right up to the forefront of modern industrial practice.

In many cases the gap is so large that equipment which industry has written off and is about to move off its production lines and out of its laboratories, may nevertheless be much better, much more modern than anything that a university might have available to it. One can think of industries helping to develop laboratories at universities by donating equipment.

Those are just a few of the examples I can think of. I am sure there are many more.

Mr. WINN. That is done very frequently and probably could be done a lot more with some examples and some encouragment.

I am familiar with some of the projects where industry, particularly the private aircraft industry, has cooperated with the engineering school at the University of Kansas by actually furnishing airplanes that are inside the engineering buildings for use by the students, and I know Michigan and Michigan State have some programs that we have seen.

Has there ever been ~~a~~ study made to show what has been done and thereby encourage there industries to participate? Or is that left up to the university communities?

Dr. LANGENBERG. Would you like to respond?

Mr. DOAN. Yes. The NSF Organic Act requires the Board to make annual reports. The 14th Board Report will deal with university-industry cooperation. The background research for that report is intended to develop as many examples of this kind of thing as we can get. It is meant to do exactly what you are talking about, to become a discussion piece that could encourage, by example, the kinds of things that can be done between university and industry. It doesn't have anything to do with education directly, but just as a background of the kind of things Don was talking about on your question.

The chemical industry, by itself, has gotten together with all of the chemical engineering and chemistry schools in about 60 universities, and perhaps 130 research directors from industry. They gather together once a year. They see the necessity for this kind of cooperation and are trying to find out how best to do it.

In addition to other things, they are going to put together a fund for supporting basic research in universities directly from the chemical industry. This thing seems to be working quite well. One of the problems is to get these people acquainted. They have to understand that they each represent good and important groups. They are doing different work, but it is quite exemplary, and necessary.

They have the tendency to—each side looks down its nose at the other. That is a bar to good cooperation. One of the things this comparative effort is accomplishing is wiping out those kinds of misunderstandings.

It will also expose the needs of universities and make apparent how the industry can help them in instrumentation.

One of the things we haven't discovered is how to translate that good idea to other industries. If we can get the pharmaceutical industry, the aircraft industry, or the electronics industry to do the same thing, this could go a long way toward promoting good cooperation.

Mr. WINN. I was just going to make one suggestion. Maybe the press people, the public relations people at NSF can work with trade journals of the various industries and possibly with the public press and media. Maybe out of those trade journal articles which can be controlled, the public press and media might pick up something to entice additional industry cooperation. If well written, it could intrigue additional students into certain fields.

Mr. **Doan**. That is an excellent idea. I think we ought to do that—use our own public information people to get into the trade journals.

Mr. **Winn**. Right. You have it in the budget over there. There might be some way to use them.

Mr. **Doan**. Yes.

Mr. **Winn**. Thank you.

Mr. **Fuqua**. Mr. Volkmer.

Mr. **Volkmer**. I would like to ask, has the new OMB signed off on this budget?

Dr. **Langenberg**. The new OMB, the budget you have transmitted to you?

Mr. **Volkmer**. Right.

Dr. **Langenberg**. It was transmitted to the Congress before the new OMB, as you call it, came into existence.

Mr. **Volkmer**. Have you reviewed it with them at all yet?

Dr. **Langenberg**. Our people have not been interacting individually with members of the staff of OMB.

Mr. **Volkmer**. So we don't know if they will come back with a change in this or not?

Dr. **Langenberg**. No, we don't know.

Mr. **Volkmer**. All right. I notice, as the gentleman from Kansas has also, that the largest increase is part of the program for the universities, for equipment, et cetera—research?

Dr. **Langenberg**. Yes.

Mr. **Volkmer**. I notice here also that you have a proposal in for the National Science Foundation's planning and evaluation support of that. There is an increase there also. Is that necessitated to evaluate what university type of equipment they will have to have, et cetera?

This is the cross-directorate programs.

Dr. **Langenberg**. In the cross-directorate programs?

Mr. **Volkmer**. Right.

Dr. **Langenberg**. There is a very significant increase there which involves a number of things of a periodic nature. I believe you will find that a very considerable part of that increase is due to funding placed there to enable the National Academy of Sciences to carry out a legislatively mandated study of the effects of increased carbon dioxide in the atmosphere.

Mr. **Volkmer**. Do you anticipate any of these increases in the total program necessitate any increase in personnel?

Dr. **Langenberg**. There will certainly need to be some shifts in personnel within the Foundation—in the case of some programs, an addition of small numbers of personnel if and when that becomes feasible. But for the most part, we do not expect any need for large additions to the current staffing of the Foundation over and above those that have already been projected and approved by OMB.

Among the principal reasons for relatively small numbers of new personnel is the ocean margin drilling program expansion. Some of our new programs are going to require small numbers of people, yes.

Mr. **Volkmer**. Other than that, there may be some shifting, but that is about it?

Dr. **Langenberg**. Some shifting and some additions, I think. But the additions will be relatively small in magnitude relative to the overall staffing of the Foundation.

Mr. **Volkmer**. I wish to join the chairman in trying to hope that you get this country moving on innovation in mathematics, sciences and engineering and I wish to commend you on your effort. Thank you very much.

Mr. **Fuqua**. Mrs. Schneider.

Mrs. **Schneider**. No questions.

Mr. **Fuqua**. Mr. Shamansky.

Mr. **Shamansky**. Mr. Chairman, thank you.

You mentioned possible assistance for students and equipment for schools. Is there any thought about assisting faculties to retain their members in case they are being attracted to private industry? I am worried about retention of skilled faculty in engineering and science.

Dr. **Langenberg**. In what I would call indirect ways, several of our proposed programs would help in that retention. I think a number of things can be identified as leading to difficulties in retaining experienced senior faculty. If I can just tick some off: one is rapidly diverging salary differences between private industry and the universities. A second is the availability of research support to allow a faculty member to carry on the research that he or she wishes to do. When that research support is very difficult to come by in an academic setting, and a Government laboratory or an industrial laboratory allows much better funding of research, that provides a temptation to leave the university.

One of the reasons that faculty members are in universities to begin with is that they enjoy interacting with students, and in particular with graduate students. When graduate student enrollments begin to decline, it becomes more difficult to find graduate students to work with and to support. That is another incentive to think about looking toward greener fields.

Yet another source of the problem that has been often referred to is increasing bureaucracy and redtape in the academic environment. Some of that has its source in the Federal Government. Some of it has its source in State governments, and some of it has its source within the universities themselves.

Each of these things individually may not be enough to cause a faculty member to say, "I have had enough, I am going to look elsewhere," but all of them together may. We are, of course, as an agency of the Federal Government, really not able to do very much about the faculty salary problem, but we can do something about the research support problem, about the instrumentation problem, both for instruction and for research, and about the graduate student problem. All three of these are being addressed in our 1982 plans.

Mr. **Fuqua**. Mr. Sensenbrenner.

Mr. **Sensenbrenner**. No questions, Mr. Chairman.

Mr. **Fuqua**. Mr. McCurdy.

Mr. **McCurdy**. Mr. Chairman, I would like to ask a couple of quick questions. I realize that we have an important vote coming up in a few minutes, so if I may, I may just ask the questions. This is an area of interest for me, and hopefully I will be on the subcommittee that will be dealing with this in more detail, but I would like to raise some concerns, and as a new member I think many of the folks back home have been voicing this for some time.

I would also like to state that I believe you have perhaps the most favorable climate or perhaps are going to have the most favorable climate you have had in some years concerning increasing spending in these areas. I think there are two areas that we, as we say back in Oklahoma, have been whipped in. One is in national defense and the Russians are doing that. The other is in research and development in high technology, and the Japanese are doing that. So I think we have some areas to move in.

One of the questions I am concerned about is the incentives to encourage postdoctoral education, again because of this drain by private industry. As I understand it, undergraduate engineers are going out and making darn near what a person with a master's or a doctorate would be making, and certainly it is a problem to provide incentive for a person to continue 3 or 4 rough years, to go ahead and get that graduate degree.

Second, I am concerned about the overall perception today of the rivalry between academic and industrial research. Perhaps you don't use the term "rivalry," but I have been lobbied already by industrial firms that have their research and their goals and their overall viewpoints and conception of what research should be and how it should be conducted. Of course having a major university in the district I represent I have that end of it also. I do perceive that the two are conflicting at times, and I am curious about your feelings there.

These are two main things that I am concerned about. Again, we have a very short timeframe in which to work, but hopefully sometime we will be able to discuss them in more detail. Perhaps you have some quick observations in those two areas.

Dr. LANGENBERG. Let me give it a try. First, the question of incentives for graduate work, particularly by engineers. What you say is true. The young engineer with a baccalaureate can look forward to income in an industrial environment which is perhaps roughly equal to what the income might be if he or she went through graduate work and took a position as a young faculty member in a university. As I said earlier in response to the question, the National Science Foundation cannot, and I believe should not, directly influence that salary differential. On the other hand, there are things that we can do within our legislative mandate to make the prospect of a life as a graduate student in engineering a little less than perfectly awful, financially prohibitive, and devoid of the kinds of tools and of the kind of faculty that a graduate student needs at that stage. Many of the programs that you will see in our plans are intended to address that.

On the rivalry between universities and industry——

Mr. DOAN. Let me try that one.

Dr. LANGENBERG. Why don't you go ahead. Wait, let me say a couple of things about it. We have got a little rivalry here.

Mr. DOAN. A little rivalry here.

Dr. LANGENBERG. Between a former university professor and an industry man. I do not see it as a rivalry for resources, perhaps for people. I do see it as a rivalry to perform the best research, and that is perfectly proper. In my own research career I found myself in direct rivalry with people in some of the leading industrial research laboratories, and that was great. Sometimes they won, sometimes I won, and I think together we collectively did better science than we would have had that competition not been there.

I think one can describe the general relationship between university faculty in the sciences and in engineering and industrial scientists and engineers over the past decade and a half as not so much characterized by rivalry as by ignorance and lack of communication. For a variety of reasons, the gap between researchers in industry and researchers in universities, I think, has widened over the past decade and a half or so. Those reasons include the decreasing participation of industry in the actual support of research in universities.

They include the events of the 1960's which created some suspicions and mistrust on each side about the other. But I think within the past 4 or 5 years there have been strong signs of a reversal of that trend. There is a realization that it is not just the universities and the Federal Government which are important in the research enterprise of the Nation. It is the universities, the Federal Government and industry, and they are all very strongly coupled together. They all need each other. They all need support from each other, and the communications and interaction among those three are extremely important. I see that attitude building both in industry and in universities. And some of our programs are designed to encourage and enhance it. In particular, I would mention the industry-university cooperative research program.

Mr. **Doan**. That is a good statement. I am not rivaling that at all.

Mr. **McCurdy**. I had perceived the difference in attitude as to the short run versus long run research. Does it have a much quicker payoff as opposed to the more protracted or questionable research in the long run? Of course, those are economic decisions also, and it is a real concern. I will make one more statement. I will apologize too, for making a chamber of commerce pitch here, but we do more than play football at Oklahoma. We also have good engineering schools and we would like to make them better.

I would like someone to provide us the procedure for receiving awards for research grants. I also want to send some copies of your budget to some folks back home to make sure they are aware of the procedure so they can get out and hustle a little bit too. I also make a pitch for some new developments in some of the educational institutions in the energy producing States. I think I would like for you all to be very supportive and certainly look at that down the pike. Thank you very much, and hopefully we will be able to go into more detail on some of these questions later.

Dr. **Langenberg**. We will be most happy to provide you the information you need.

Mr. **Fuqua**. Mr. Dymally.

Mr. **Dymally**. No questions.

Mr. **Fuqua**. Thank you very much for I think a very responsive statement and presentation before the committee today. We look forward to our hearings where we go into more detail, and I am sure there will be many more questions asked. We do thank you very much for being here today and making your presentation. The committee stands adjourned.

[Thereupon at 3:10 p.m. the committee was adjourned.]

1982 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

TUESDAY, MARCH 3, 1981

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcommittee met, pursuant to notice, at 2 p.m., in room 2325, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. Walgren. The committee meeting will come to order. According to the committee rules, it is necessary that we have unanimous consent of the members present for photographic coverage of this hearing. I, therefore, do ask unanimous consent that photographic coverage be permitted. Hearing no objection, we will follow that procedure for this particular hearing.

I want to welcome to the committee one of the most distinguished former Congressmen, especially in the scientific area, Mike McCormack from the State of Washington. Before calling Mr. McCormack, I would like to read an opening statement and give an opportunity for other members present—perhaps others will be here at that time—to do the same.

Today begins the first of 4 days of hearings on the National Science Foundation. I want to say at the outset that these 4 days will not be sufficient to cover all of the Foundation's programs. Nor, will we be addressing all the major issues directly related to the responsibilities of this agency. Rather we have chosen to focus our attention on a few of the more critical issues and programs in the hopes of targeting our resources and thereby obtaining greater, in-depth understanding.

The issues we will be discussing are: Science and engineering education; applied science, engineering and innovation; and behavioral and social sciences.

Today's hearing will focus on science and engineering education. I believe, and I think our witnesses today and in later sessions will concur that we are faced with a major crisis in science and engineering education. Examining the recent report, "Science and Engineering Education in the 1980's and Beyond: A Report to the President," and others, we find:

Only one-sixth of secondary school students take science or math beyond the 10th grade.

Only one-third of the Nation's 17,000 school districts require more than 1 year of mathematics or sciences; while admission standards to colleges and universities have declined.

There are 40 percent more undergraduate students in engineering today than 10 years ago. There is correspondingly 10 percent fewer faculty.

Laboratory, instructional, and research equipment has degraded to the point of obsolescence, and we must question our competitiveness with the teaching standards in Japan, Western Europe, and even the Soviet Union.

It is estimated that $2 billion is necessary to remedy only the instructional equipment problem.

Increasingly salaries, particularly in such fields as computer sciences, have drained our faculty and decreased both the quality and the quantity of potential new faculty entering graduate schools.

The grim statistics go on.

Distressing as this information is, I am more distressed by the reductions apparently being proposed for NSF, the major Federal entity now supporting science and engineering education. We are told that in lieu of increasing funding to begin addressing the needs just cited, particularly in engineering education, the Foundation and the President will recommend that the entire Science and Engineering Directorate be eliminated.

Whereas reductions in NSF's overall programs may prove necessary, I believe we must carefully examine the wisdom of cutting back entirely such an important segment of the Foundation's and this Nation's science and engineering activities.

We have a number of distinguished witnesses who will address this issue today. Dr. Carl Sagan, renowned narrator and producer of the "Cosmos" TV series, is expected to arrive shortly and will join Dr. Guy Stever who currently heads the National Academy of Sciences Assembly of Engineering. Before turning to Dr. Stever, I would ask whether other members of the committee have either opening remarks or comments they would like to make.

Mr. **Ertel**. Mr. Chairman, I did not have prepared remarks to make at the opening of this session, but I do think it is important that we keep in perspective the things that we are going to be addressing in a series of hearings on the National Science Foundation. I believe that we have room for cuts in cutting the budget of the United States.

We need to eliminate fraud, waste, and abuse, and a lot of other things. But I think we must look carefully at the elements that we cut. I think sometimes we tend to look at the short term rather than the long term. We are going to cut back on such things as science education and engineering application, those elements which would increase the productivity of the United States and also satisfy the requirements for a future generation.

I think short-term cuts which may balance the budget may be selling out our long-term interest in the betterment of our society. That is why I am looking forward very much to these hearings to determine whether or not the administration's programs and their proposed cuts into the areas of science and science education really will serve the American people in the long run. I suspect not. This is one of the areas where we have a commitment to the future, and it is important for us to have that.

Thank you, Mr. Chairman.

Mr. **Walgren**. Mr. Shamansky.

Mr. **Shamansky**. Mr. Chairman, I would like to second what Mr. Ertel has said. I am especially interested in this area because my community has Ohio State University, the Battelle Memorial Institute, Chemical Abstracts, and something called OCLC, which has computer library sciences. The idea that we will now cripple the teaching and training of students as scientists that we need as a country to compete with the Japanese, the Western Europeans, and the Russians at this time to me is a staggering notion. So I also will look with great interest to see the justification, in advance, for it—in effect the morality for it—to effect a short-term benefit, so-called.

Mr. **Walgren**. Thank you, Mr. Shamansky.

I want now to turn to our first witness, Mike McCormack, a Member of the House of Representatives for a significant number of years. Mr. McCormack was really the most knowledgeable scientific resource as a Member that the House had in its body in the 1960's and the 1970's. He has made an invaluable contribution to the state of science in our country. He also used to be involved in science education and as such has a special background as an educator with special sensitivity to the importance and the value and the contribution that efforts in this area can bring.

I want to welcome you to the committee. We appreciate your coming and being here with us.

STATEMENT OF HON. MIKE McCORMACK, A FORMER REPRESENTATIVE IN CONGRESS FROM THE STATE OF WASHINGTON

Mr. **McCormack**. Thank you, Mr. Chairman. Chairman Fuqua, members of the subcommittee, ladies and gentlemen: First of all, Mr. Chairman, I think you are aware that, because I am here on a last-minute schedule, I do not have a prepared statement. I apologize for that, but I shall attempt to talk slowly so that your good reporter can make a record of what I am saying.

Mr. **Walgren**. We appreciate that you could accommodate the committee as you have.

Mr. **McCormack**. Thank you. It is good to be back, Mr. Chairman. It is good to be home with you, and I do appreciate this opportunity.

I come here today to urge your full support and your authorization for full funding for the National Science Foundation science and engineering program. I have asked to come before you because I am deeply troubled by the state of the education system in this country, in its quality, in its ability to provide basic science and mathematics for most of our students, and the desperate situation we face as a nation in attempting to provide the number of qualified graduate engineers and scientists that this Nation must have if it is to survive; indeed, if it is to compete in international industry and commerce.

Let me elaborate on some of the symptoms of this problem. I think you are aware of the declining SAT scores. To me this is an alarming matter. It is interesting to note that engineering and science students applying for university and college entrance have generally the same high SAT's that they have had in the past. This indicates that we have a small percent of students with high scores, and a larger number whose scores are even lower than we suspected.

It shows that the situation is worse than it appears.

All of you who are not freshmen have had the experience of considering applications for our military academies. In considering applications for the academies, I generally placed most emphasis on SAT scores and grade transcripts. Then I eliminated those least qualified, and nominated the best students.

In the past, but particularly when I started in 1971, I looked for 4 years of math and 4 years of science and 4 years of English and a couple of years of language as the basic criteria for excellence for applicants to our military academies. Over the 10 years of the 1970's, I saw a decline in the quality of academic work in applications, with students asking for nomination to the academies with perhaps 1 year or 1 semester of mathematics, or 1 year of what was referred to as science, but which frequently was not.

It is alarming to me that our high schools are not counseling our students to undertake the curricula that is necessary for us to have good scientists and engineers, or, indeed, a good understanding of the problems we face.

My third point is that there is an alarming reduction in the number of U.S. citizens in graduate schools in science and engineering and mathematics. Your staff can provide you with numbers in this, but I would like to call to your attention a comment that was made to me yesterday. I was visiting the Phillips Petroleum Co., participating in a series of discussions with Phillips executive and technological personnel at Bartlesville, Okla. One of the comments made at that time was that we do not have adequate faculty in our high schools and colleges, and that we are filling our faculty ranks with citizens of other nations.

Obviously, I do not object to immigrant scientists but when we have done so poorly that we must, out of necessity, depend upon imported scientists and engineers to teach our students, we are in a desperate situation.

There is a strange twist in all of this. It is that there has been a substantial increase during the last several years in science and engineering applications to our colleges and universities. Many students now graduating from our high schools have been informed that there will be a demand for scientists and engineers, so they are applying to study science and engineering in the universities, but many of these students lack adequate training in science and mathematics.

Even more importantly, we have a shortage of faculty. I understand that there is a shortage of 2,000 faculty positions in engineering alone in this country. That says nothing of science or mathematics. Even the most prestigious of universities and colleges, such as MIT, are having difficulty in getting topflight scientists and mathematics faculty and engineering faculty.

For instance, in solid state physics, industry is outbidding our education system for both graduate students and for good faculty. In a way we are creating this problem by the scientific programs that we are stimulating here in the Congress. Every time we initiate a program in solar photovoltaics or nuclear fusion or synthetic fuels, we are creating more pressure on the industry, so the Congress has contributed to this portion of the problem.

I am told that one petroleum company plans to hire 25,000 new engineers in the next 10 years. That would absorb almost the entire production of the entire country. This is a measure of the seriousness of the problem we face today.

There is another facet to it, too, and that is that engineering students with only a baccalaureate degree are receiving in some cases more than 50 percent of the salaries of Congressmen. Such salaries are being paid to students coming out of college with only 4 years of study without any graduate training at all. The result is a lower quality of education and fewer graduate students and scientists. This is the state of affairs at both the student level and at the faculty level.

I think it is axiomatic that the critical factor in the progression and growth of any society is brain power, and in a technical society such as ours, it is scientific, engineering and mathematical brain power.

Today in the District of Columbia we are in the midst of an attempt to establish a program called Operation Rescue. Maybe some of you have read about it in the newspapers. It is to save the first, second and third graders in the elementary public schools in Washington, D.C. from the projected 40-percent failure rate that is presently anticipated because these students cannot read or do math well enough to be promoted. In Operation Rescue adult professionals are being asked to volunteer to help teach children.

I hope to participate in this program. I think it is important. However, there is a basic question, and that is this: Why is it that students in the first, second, and third grades can't even handle such basic things as math and the ability to read? And why is it that our teachers in our schools today feel that they cannot succeed during the next 10 weeks in raising these student skills enough for them to pass.

I think what we are experiencing is a descending spiral of excellence. It is feeding upon itself, and it is literally unable to help itself within the education community alone.

The American Chemical Society's magazine, Chemical and Engineering News for February 9 has an excellent editorial on this subject, in which the editor says—and he is comparing the situation in education to that of a farm, it is the same as farmers eating their seed corn. Fundamentally, that is what we have been doing and are doing today in education.

Mr. Chairman, I would like to submit this editorial and an excellent article from the Chemical and Engineering News for the record if I may.

[The information follows:]

Chemical education falls on hard times

Deteriorating quality of chemical education is felt most acutely in chemical engineering because of growing faculty shortages and equipment obsolescence

Ward Worthy
C&EN, Chicago

Is there a crisis in science and engineering education? There have been rumors of one. Cynical observers might comment that there *always* seems to be a crisis in education, either at hand or just ahead. Educators do spend a lot of time contemplating their craft. Furthermore, educators are prone to voice their contemplations in lengthy reports. These reports often warn of the disasters that will occur if their recommendations aren't followed. Sometimes they overstate the case.

This time, however, there's a fair amount of truth in the rumors. There's certainly evidence that the quality of education in many fields of engineering, including chemical engineering, is being endangered by severe and growing shortages of competent faculty. The situation is made worse by the fact that much engineering teaching equipment is inadequate, obsolete, or just worn out. Similar problems, as yet less acute, beset the teaching of the basic sciences, including chemistry.

One of those lengthy reports that educators are fond of is the recent "Science and Engineering Education for the 1980's and Beyond." It was prepared by the Department of Education and the National Science Foundation (with input from many outside sources), under the direction of former Secretary of Education Shirley M. Hufstedler and former acting NSF director Donald N. Langenberg (C&EN, Nov. 10, 1980, page 37, and Nov. 17, 1980, page 56).

The Hufstedler-Langenberg report, as it has come to be called, makes two main points. One is that recent trends in general education are leading the U.S. toward "virtual scientific and technological illiteracy." Except for the relatively few who take up careers in science or engineering, the report says, today's students, in high schools and in colleges and universities, are studying much less science and mathematics than their predecessors did. This bodes ill for the nation, the report adds, because it means that important decisions on science and technology increasingly will be made by people who are ignorant of both.

The second main point the report makes is that in 1990, the U.S. will, in aggregate, have more scientists and engineers than it will have scientific and engineering jobs, and that some of these scientists and engineers will have to look for other kinds of work. The report does note that there are current shortages of computer professionals and of most types of engineers, at all degree levels. Otherwise, it finds, there already are more than enough scientists, except in a few specialties, to fill existing needs.

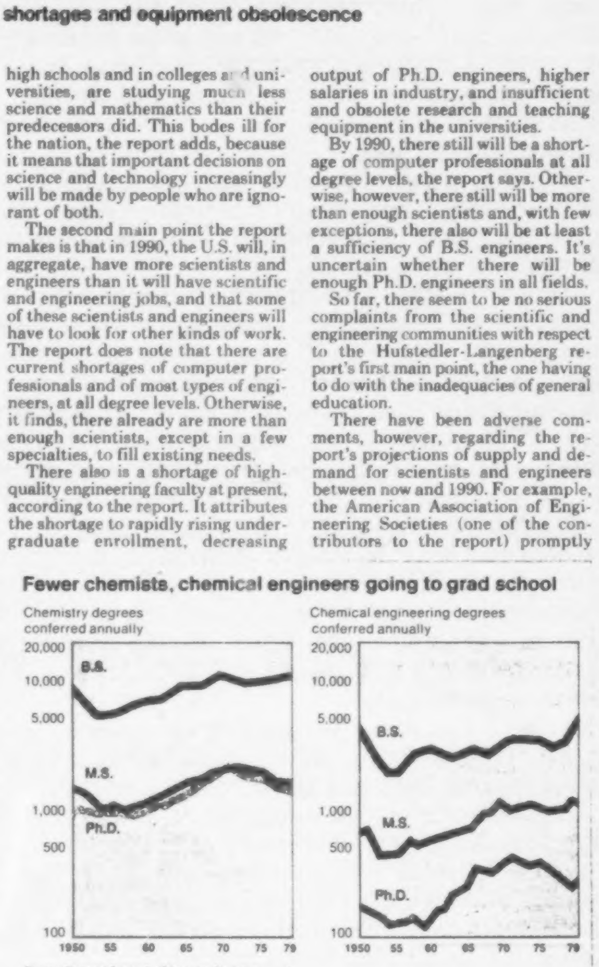
There also is a shortage of high-quality engineering faculty at present, according to the report. It attributes the shortage to rapidly rising undergraduate enrollment, decreasing output of Ph.D. engineers, higher salaries in industry, and insufficient and obsolete research and teaching equipment in the universities.

By 1990, there still will be a shortage of computer professionals at all degree levels, the report says. Otherwise, however, there still will be more than enough scientists and, with few exceptions, there also will be at least a sufficiency of B.S. engineers. It's uncertain whether there will be enough Ph.D. engineers in all fields.

So far, there seem to be no serious complaints from the scientific and engineering communities with respect to the Hufstedler-Langenberg report's first main point, the one having to do with the inadequacies of general education.

There have been adverse comments, however, regarding the report's projections of supply and demand for scientists and engineers between now and 1990. For example, the American Association of Engineering Societies (one of the contributors to the report) promptly

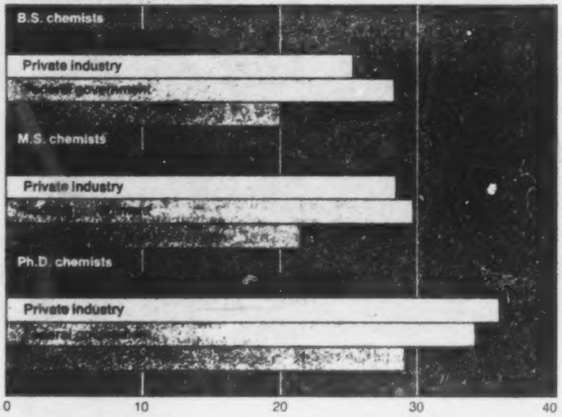
Fewer chemists, chemical engineers going to grad school



Source: National Center for Education Statistics

Academic chemists make less money

Median annual salaries, $ thousands



Source: ACS Salary Survey, 1980

charged that the report underestimated the "growing crisis in engineering education that endangers U.S. reindustrialization." According to AAES executive director Donald E. Marlowe, the report doesn't adequately confront the immediate problems of engineering teacher shortages and obsolete equipment.

"Failure to ensure quality engineering education will make it unlikely to achieve the government's projection that, for the most part, there will be enough well-educated engineers to meet the country's high-technology needs," Marlowe says.

Narrowing the focus, many chemistry teachers believe that the report fails to give enough weight to declining graduate enrollment and that it thus overestimates the future supply of Ph.D. chemists. As a group, however, they aren't ready to proclaim a crisis. Chemical engineering teachers, on the other hand, tend to confirm that the picture is at least as grim as the report paints it, insofar as chemical engineering education is concerned.

According to figures compiled by the National Center for Education Statistics, production of B.S. chemical engineers remained fairly constant from 1969 through 1977, averaging about 3500 per year. During that same period, the number of M.S. degrees awarded yearly in chemical engineering also was steady, averaging about 1070, or about 30% of the number receiving B.S. degrees. Yearly production of Ph.D.'s in chemical engineering averaged about 376, or about 11% of the B.S. average. However, Ph.D. degrees peaked at 438 in 1970; thereafter, the trend was generally down, to only 291 in 1977, only about 8% of the B.S. number that year.

Although the supply of new chemical engineers remained about the same from 1969 through 1977, demand for them began to grow in 1975 and since has continued unabated. Competition for the available graduates has become very keen. Starting salaries offered to new chemical engineers are among the highest offered to graduates in any field. For example, a recent survey of 4670 employers made by Fox-Morris Personnel Consultants reveals that 1981 salaries for entry-level B.S. chemical engineers will average $21,500 (compared to a $14,760 average for liberal arts graduates). The survey also notes that the companies' broad-based engineering needs will rise some 19% from 1980 levels.

Naturally, more students are now going into chemical engineering. In 1978, U.S. schools turned out 4615 new B.S. chemical engineers, a 29% increase from 1977's 3581. In 1979, the figure rose to 5655, up 23% from 1978 and 58% from 1977.

It should be noted that 1978 was the first year in which the number of new B.S. chemical engineers broke the record of 4529 that was set in 1950, or even exceeded the 3756 that graduated in 1951. Then, of course, U.S. universities were crowded with World War II veterans. After that, enrollments declined. Now, in universities as well as in industry, the engineers from those "bumper" years are approaching retirement. That's one reason demand for new engineers has mushroomed.

Even the 5655 new U.S. chemical engineers that graduated in 1979 weren't nearly enough to fill the needs, industry sources say. If the present trend of increasing enrollment were to continue, it wouldn't take very long for supply and demand to reach balance, just as the Hufstedler-Langenberg report suggests. But the trend isn't likely to continue, if for no other reason than that the chemical engineering education establishment is already overloaded and can't accommodate many more students. In fact, it's becoming increasingly hard for many chemical engineering departments just to maintain existing standards.

Despite the big increase in undergraduate enrollment, there's been no corresponding increase in the numbers of graduate chemical engineering students. The number of M.S. degrees rose to 1237 in 1978 but fell to 1139 in 1979. That's only slightly above the average of 1070 for the 1969–77 period.

The number of Ph.D. degrees dropped to 259—the lowest in 15 years—in 1978, then rebounded to 304 in 1979. That was still well below the 1969–77 yearly average of 376 and only 5% of the number of B.S. degrees. Also, about 40% of the graduate chemical engineering students were foreigners, most of whom weren't available for employment in the U.S. That left maybe 200 new Ph.D. chemical engineers who were available for employment in 1979, when there was work for many more. For example, just one company, Du Pont, says it easily could hire 30 to 40 new Ph.D. chemical engineers every year.

The combination of expanding undergraduate enrollment, shrinking graduate enrollment, and high industrial salaries is making it difficult for chemical engineering departments to retain their present faculties, let alone expand them.

To determine the extent of the problem, Dee H. Barker, a professor of chemical engineering at Brigham

Young University in Utah, surveyed U.S. chemical engineering departments. Discussing his findings in a recent issue of *Chemical Engineering Progress*, Barker notes that of 120 schools responding to his questionnaire, 83 had positions open. Of a total of 1157 full-time faculty positions, 172—about 15% of the total—were vacant. Even allowing for part-time faculty (which swells the total to 1383), Barker adds, the ratio of students to faculty is now about 25:1, which is high.

Marshall M. Lih, director of the National Science Foundation's chemical and process engineering division, says the situation is actually worse than the 15% vacancy rate indicates. He estimates that it would take 200 to 250 new full-time faculty members to put U.S. chemical engineering departments into really good shape.

Some chemical engineering classes are as large as 200 students, Lih notes. "If a chemical engineering professor gives a one-hour quiz," he says, "his whole week is shot, because it takes 30 to 40 hours to grade those 200 papers." The shortage of graduate students means there also is a shortage of good teaching assistants, Lih says, adding that because of language and cultural problems, most foreign graduate students can't serve as assistants, at least not during their first couple of years.

With industry and universities competing for a dwindling number of Ph.D. chemical engineers, it's obvious who's going to win. Darsh T. Wasan, chairman of Illinois Institute of Technology's chemical engineering department, notes that starting salaries for new assistant professors are now in the range of $20,000 to $22,000, for nine months. He adds that he hasn't been able to hire any at that price lately. Then he cites the case of one of his graduate students, working on an enhanced oil recovery project, who hadn't yet finished all his Ph.D. requirements. That student left to take a $35,000 position in industry; his employer will sponsor his thesis work. Similar tales abound.

Salaries don't tell the whole story, Wasan adds. Today's housing market and high mortgage rates also put the universities at a disadvantage. "I almost had an assistant professor hired," Wasan relates. "But the deal fell through because he wasn't able to get rid of his old house in California and buy a new one here in Chicago." Companies routinely absorb many of the burdens of relocation; as a rule, universities can't or won't.

Although academic salaries probably never will match industry salaries, there can be compensations. "You teach because you love it," Wasan says, "and because you have a great deal of freedom to do what you want to do."

But love and freedom don't pay the rent. With the current differences between industrial and academic salaries, it's little wonder that almost all the new Ph.D. chemical engineers choose to go to industry, regardless of what that might mean to the future of chemical engineering education.

The current seller's market for B.S. chemical engineers has much to do with the decline in graduate enrollments. True, Ph.D.'s make more money than B.S.'s. But it's hard to convince new B.S.'s that it's to their ultimate advantage to spend three or four years as impoverished graduate students, when they can go out and make big money right now. It's almost impossible to persuade the new B.S. to get a Ph.D. with the aim of going into academic life when starting salaries for B.S. chemical engineers in industry are as high as starting salaries for Ph.D. assistant professors.

Universities also are increasingly unable to compete with industry in terms of engineering laboratory equipment. The American Society of Engineering Education, examining the whole engineering field, found that most engineering teaching equipment dates from the 1950's and that equipment for new "growth technologies" is almost nonexistent in university labs. ASEE estimates the cost of updating teaching equipment and modernizing classrooms and buildings would run about $40 million per year.

Wasan: you teach because you love it and because of the freedom

It's hard to get a "handle" on what it would cost to modernize the nation's universities' chemical engineering laboratories. IIT's Wasan notes that in this computer age his labs still must meke do with "a lot of old pneumatic stuff." He estimates that it would take about $180,000 to bring things up to date.

NSF's Lih comments that "you could double the equipment budget, or increase it five times, and still show a need for more, because the academic chemical engineering labs have been so poorly equipped in the past.

Illinois Institute of Technology students using obsolete equipment

Academic chemist hiring pace speeds up

Every spring the American Chemical Society's Office of Manpower Studies surveys most U.S. chemistry departments to determine their hiring plans for the coming academic year. Usually, actual hiring falls short of the plans but correlates fairly well with them.

In 1977, the estimated total came to 294; in 1978, 310; in 1979, 307. In the spring of 1980, however, U.S. chemistry departments anticipated that they would hire 513 academic chemists, 67% more than the 1977–79 average.

Of the total, 352 were tenure-track faculty positions. That number represents a 45% increase from the 1977–79 average for that category. Nontenure-track positions, either temporary faculty or nonfaculty support personnel, accounted for the other 162. That number represents a rather startling 159% increase from the 1977–79 average. And of the 513, 427 (81%) will replace persons leaving departments; only 96 (19%) represent departmental expansions.

The 1980 survey reveals no great changes in the apportionment of openings among the various subdisciplines of chemistry. In terms of percentages, demand for biochemists and (despite alleged shortages) analytical chemists has softened somewhat, relative to the 1977–79 average. In terms of actual numbers, however, demand for those categories, like the others, rose significantly, compared to the average for the preceding three years.

There were some notable differences in 1980 hiring plans of schools that offer the Ph.D. and schools at which the M.S. is the highest degree awarded in chemistry. At the Ph.D. schools, for example, 96% of the positions required a Ph.D. in chemistry; at the M.S. schools, only 86%.

At the Ph.D. schools, 64% of the openings were for tenure-track appointments, 25% for temporary faculty appointments, and 11% for nonfaculty support positions. At the M.S. schools, 62% of the openings were for tenure-track appointments, 36% for temporary faculty appointments, and only 2% for nonfaculty support positions.

Also, at the Ph.D. schools, 20% of the openings were for department expansion; at the M.S. schools, expansion accounted for only 14%. Biochemists were in much greater demand at M.S. schools and physical chemists were somewhat more in demand at Ph.D. schools. Demand for other specialties was about equal in both types of school.

Chemistry hiring rises an estimated 67%

	Academic year			
	1977–78	1978–79	1979–80	1980–81
Chemistry departments surveyed	325	324	323	322
Chemistry departments responding	318	324	323	291
Estimated total size of departments	5575	5776	5872	5905
Estimated anticipated hiring	294	310	307	513
Tenure-track	243	233	247	351
Nontenure-track	51	77	60	162
Distribution of openings by specialty				
Biochemistry	11.6%	14.5%	12.1%	9.7%
Analytical chemistry	18.0	25.2	21.8	18.9
Organic chemistry	26.2	20.6	25.4	26.3
Physical chemistry	17.0	15.8	15.6	19.1
Inorganic chemistry	13.9	13.5	13.4	12.8
Other	13.3	10.3	11.7	13.2

Sources: ACS Office of Manpower Studies

What's really needed is an order-of-magnitude increase and improvement. Then people can do research that will be a quantum leap compared with what they've been doing."

Particularly needed are new large-scale test facilities, Lih says; also, most facilities have inadequate instrumentation. But "in general, we need better regular-size teaching equipment, not just major facilities."

The equipment problem is one contributor to the faculty shortage, Lih says. "When a new Ph.D. comes out, he not only looks at the salaries, he also looks at the facilities available in industry versus those available in the universities, and there's no comparison." Lih also notes that in industry, "If you need something, you can get it right away, because every day can mean thousands of dollars saved. But in the university, you've got a lot of problems, including trying to get a grant from NSF to buy it. The lead time could be a year." And, of course, you might not get the grant at all, no matter how good the justification.

In the past, it has been said, NSF has tended to favor basic research at the expense of science and engineering education. There are indications, however, that the situation is changing. For example, the proposed NSF budget for fiscal 1982 includes a new $25 million program for updating university laboratories. In addition, the chemical and process engineering division would receive $22.1 million, 22% more than in fiscal 1981.

There have been numerous suggestions as to how to attract more chemical engineers into graduate study in general and, in particular, into chemical engineering faculties. Most of the proposals are predictable: more fellowships, more grants, more active recruiting, and extension of programs aimed at encouraging minorities and women to take up engineering careers.

One thing all these proposals have in common is that they cost money. With the current demand for cutting, rather than increasing government spending, it's evident that the government can't do it all. It's equally evident that little more can be expected from the universities themselves. Indeed, many U.S. universities, both public and private, are in serious financial difficulty.

For example, Irving Shain, chancellor of the University of Wisconsin, Madison, contends that "higher education has been eroded rather dramatically." State universities generally have been subjected to a "whole series of random budget cuts and recalculations of enrollment funding formulas."

In Wisconsin, Shain notes, enrollment funding formulas were suspended twice in the past decade, both times during periods of rapid growth in enrollment. "All in all," he says, "we're teaching about 6000 more students than we ever got money for." The shortfall has been compounded, Shain points out, by inflation, "which has never been funded properly."

To make the situation worse, many states, with revenues down because of the lagging economy, imposed midyear budget cuts on the state universities. "All these cuts happened after the beginning of the fiscal year, when commitments were already made, and it led to absolute chaos at these universities," Shain says. "The net result is a very dangerous situation for the future of the country."

What does a university do when faced with sudden budget cuts? "You can't lay off faculty or staff," Shain says, "because that just wrecks the university. So you 'freeze' the things you can. The first thing you do is 'freeze' all the open positions, even if it causes serious disruptions of programs." The university at Madison currently is operating with about 285 vacant positions, Shain notes. "Then you 'freeze' the supplies and capital budgets."

The crisis in scientific instrumentation is really serious, Shain says. Many of the universities around the country got their scientific equipment 10 to 20 years ago when they built their buildings; the equipment was part of the capital investment. But there was never any money in the operating budget to allow for depreciation of that capital investment.

Now, Shain says, "We, just like many other universities, are in a very serious situation. Our buildings are 15 or 20 years old, and so is the equipment, and it's wearing out. We're training people on equipment that is out of date and far behind industry standards. When our students get into industrial positions, they have to be retrained to use the modern equipment."

The impact on higher education is bad enough, Shain says. But even worse is the impact on basic research, most of which is carried on in the universities. Without basic research, "you've got some real problems," because the health of the U.S. economy depends upon its making up in technological innovation what it lacks in productivity. "We've got ourselves so badly tied in knots by bureaucracy and unions and everything else that we can't be productive. Therefore we have to be creative. And we can't be very creative if the basic research isn't done.

"If the federal and state governments are both going to bail out on us, then we have to find some new mechanism for supporting basic research in the universities," Shain says. "It looks to me as if the chemical industry is the only hope for basic research in chemistry."

Actually, the problems of graduate education and of basic research in the universities are closely intertwined. In the long run, it will be difficult if not impossible for universities to mount successful research programs if they don't have a continuing adequate supply of eager, hard-working graduate students and research assistants. So it's as reasonable to ask the chemical industry to support graduate education in chemistry and chemical engineering as to ask it to support basic research in those fields.

Indeed, a lot of homilies have been delivered lately on the virtues of industry-academic cooperation. Responsible chemical educators emphasize, however, that there's a lot more to industry-academic cooperation than "you give us money and we'll spend it."

For example, IIT's Wasan agrees that chemical engineering schools deserve more support from chemically oriented companies. "After all," he says, "they are the major users of our product." But, he adds, more is needed from industry than money. "We need interaction. We need involvement. That's why we have representatives of 20 industrial companies on our advisory board."

That way, Wasan says, "I can show them how I can return them $2.00 for every $1.00 they invest in us." Also, such interaction can lead to the production of chemical engineers better suited to industry's needs. "I can ask them, 'What would you like to see in my graduates? What's lacking?' I can't sit here and dream about industry's needs; they have to tell me."

Wasan suggests that industry should make greater use of chemical engineering faculty members—particularly the junior ones—as consultants. "I could hire assistant professors at $22,000," he says, "if I could assure them that they could make another $10,000 consulting one day a week for local companies."

Alan L. McClelland, personnel administrator for Du Pont's central research and development department agrees with that—but only partly. Certainly, he says, the chemical industry has a long history of hiring academic people as consultants and using them effectively. However, he adds, "Industry hates to get put in the position of hiring consultants as a kind of charitable contribution. We want to hire consultants because they're genuinely useful."

McClelland also points out that Du Pont doesn't rely solely on senior faculty as consultants. "We do hire some of the really bright young people that are just getting started in the academic world," he says. "Partly because we like to 'get them on board,' as it were, and partly because, particularly in the research area, some of those people right at the beginnings of their careers are very creative. Creativity doesn't depend on long experience."

However, McClelland says, "The more you get over to the business side and possibly to the applied side, the more valuable background and experience become. There is a difference, depending on the kind of consulting you need."

Like many other chemical companies, Du Pont does provide considerable support to education. At Du Pont, McClelland says, direct aid, in the form of gifts and formal programs, currently amounts to about $4 million a year. He "points with pride" to a fairly new program of young faculty grants.

"We make grants to departments specifically for the support of young faculty members—selected by the departments—who need help in getting research programs started and in attracting graduate students, at a time when they don't have the prestige needed to get government grants." That program has been well received, McClelland says, adding that "maybe that's the kind of thing industry should get into more."

If chemical engineering education clearly is approaching a crisis, chemistry education clearly is not. Last year, chemistry departments' hiring plans were more ambitious than they had been for many years, with total

McClelland: we want to hire consultants because they're genuinely useful

hiring expected to increase 67%. To what extent those plans may have been scaled down since, because of budget cuts of the sort that Wisconsin's Shain describes, isn't yet known. In any event, it's still possible, according to all reports, to fill academic chemistry positions with well-qualified people.

Just the same, there are subtle signs that the quality of chemistry education also is deteriorating, or is heading in that direction. At this point, however, it's easier to defend that assertion with anecdotes than with data, which, as one chemistry professor puts it, are "always a couple of years behind."

As with chemical engineers, there was a postwar proliferation of new B.S. chemists, peaking at 10,619 in 1950. Thereafter, the yearly numbers of new chemists dropped off until 1954, then began a smoothly rising trend that has persisted to the present. In 1979 there were 11,643 new B.S. chemists, the National Center for Education Statistics says. However, a larger proportion of today's B.S. chemists are using the degree to facilitate entry into some other field, such as medicine, rather than with the aim of pursuing professional careers in chemistry.

The post-World War II boom in new Ph.D. chemists came a little later, in 1951, when 1046 Ph.D.'s were awarded in chemistry. Annual production of new Ph.D. chemists was fairly steady from then until the early 1960's. Around that time, in the "post-Sputnik" era, several studies by prestigious groups pointed out alarming deficiencies in U.S. science, particularly in the area of basic research. The reports of those groups called for greater federal support of science. That support was forthcoming. Rather quickly, becoming a scientist was the patriotic thing to do.

Shain: we're teaching about 6000 more students than we ever got money for

Between 1960 and 1970, annual production of Ph.D. chemists more than doubled, peaking at 2208 in 1970. That year, in fact, brought forth more new Ph.D. chemists than M.S. chemists. In other years, the numbers of M.S. and Ph.D. chemists have tracked fairly closely together, but with M.S.'s running slightly ahead.

By 1970, however, there were, apparently, more Ph.D. chemists than the U.S. could support in proper style. Federal funding fell off. Several lean years followed. In particular, academic employment opportunities for new Ph.D. chemists became almost nonexistent, even though many chemistry departments, with frankly stagnant faculties, could have benefited mightily from infusions of new blood.

The message to undergraduate chemistry students was clear and they reacted appropriately. Since 1970 the number of new Ph.D. chemists has fallen every year. In 1979 there were only 1518, 31% fewer than the 1970 peak. In the same year M.S. degrees in chemistry totaled 1765, 23% fewer than the M.S. peak of 2284 in 1971.

Meanwhile, demand for Ph.D. chemists has picked up again, particularly in industry, which has come to realize that it's imprudent to cut back on research efforts, regardless of cyclical variations in the economy. Currently, supply and demand are in pretty good balance. Most of those Ph.D.'s who were surplus seven years ago are now doing very well. Last year's crop had no difficulty finding good jobs, at good salaries.

Numbers aside, the question has been raised whether the quality of today's graduate chemistry students is as good as it was in the good old days. Douglas C. Neckers, chairman of the chemistry department at Bowling Green (Ohio) State University, has made a detailed study of Scholastic Aptitude Tests scores, grade point averages, and other indicators of quality (C&EN, Dec. 17, 1979, page 17). He concludes that, on the whole, graduate chemistry schools no longer get the cream of the undergraduate crop; the best students are, instead, going to medical school. Many academic chemists agree with Neckers' reading of the situation, but many others do not.

Certainly, however, chemistry departments, like chemical engineering departments, are having a harder time competing with industry for the cream of the Ph.D. crop. That's only natural, says Gerhard G. Meisels, chairman of the chemistry department at the University of Nebraska.

"If you take the total of Ph.D.'s granted in chemistry and subtract the ones granted to foreign citizens on temporary visas, you wind up with an annual supply in the range of 1350," Meisels says. "Then you look at the current work force and see that there are about 40,000 employed Ph.D.'s in chemistry. It's pretty easy to figure out that the country needs more than 1350 new Ph.D. chemists per year to keep operating."

At present, Meisels says, there are more jobs available for Ph.D.'s in industry than there are people to fill them. Consequently, industry salaries have been going up; they're much better than in the universities.

According to the American Chemical Society's salary survey for 1980, the median salary for all Ph.D. chemists was $36,000 in industry, only $25,000 in colleges and universities. The same survey showed the 1980 median salary for a new assistant professor to be $16,000; his counterpart (in terms of experience) in industry was making a median $26,800.

"Industry is approaching people in universities, and universities are going to lose some of their faculty to industry," Meisels says. "That's what's created the employment market in universities—that is, the tenure-track faculty openings."

As to the growth in nonfaculty academic openings, much of it can be attributed to the increasing cost and complexity of chemical instrumentation. Thirty years ago, Meisels notes, the infrared spectrometer was the most complex instrument in the department. One graduate student would spend four afternoons a week running it for the rest of the department.

Now, Meisels says, "A contemporary chemistry department has maybe a $400,000 mass spectrometer, a $400,000 NMR spectrometer, $150,000 or more in x-ray equipment, and so on. You simply can't run all that with student help. Students make mistakes and cause downtime. You need permanent, technically competent people." So more universities are hiring professionals to operate and maintain the equipment on a continuing basis.

What about the reports that project at least a sufficiency and

Nebraska's Gerhard Meisels confers with student

perhaps an excess of Ph.D. chemists in the decade to come? "Absolutely wrong," Meisels says, "and there are plenty of indicators. If you're in a university, for example, it's almost impossible to hire a postdoctoral fellow. Of those you can hire, about 75% are foreigners.

"People who were having a hard time finding jobs four or five years ago are now inundated with offers. I have a fellow, a physical-analytical chemist, who a few years ago came to work with me in a nonfaculty position because he just couldn't get a permanent job. Recently he decided to look around and see what he could find. He sent out 15 letters and he's already scheduled eight interviews."

The earlier projections of a surplus of Ph.D. chemists were based on the incorrect assumption that the number of Ph.D.'s would continue to rise, Meisels says. Instead, the number has continued to decline and the supply has been erroneously overestimated.

But a turnaround may be near. "Salaries for Ph.D.'s in chemistry are going up fast," he says. "The larger the disparity between B.S. and Ph.D. salaries, the more likely students are to go to graduate school."

Along that line, Du Pont's McClelland comments that "in chemistry, my reading is that things are at about the right balance. We have to recruit with some vigor to find the people we really want. The good people are getting a number of offers. I think that's a healthy situation, compared to having a large excess. We find it frustrating to have to turn down a whole raft of good people." That situation does prevail currently with the biological sciences.

As for easing the growing difficulty of filling faculty positions with the best possible candidates, "there's only one way," Meisels says. "University salaries are going to have to go up." Actually, he adds, that's already happening, at least at the major universities; the situation is still quite different at the smaller liberal arts colleges.

"People in universities always will make less money than in industry," Meisels says, "but there is a crossover point." If an industry chemist makes $30,000 a year and an equally qualified university chemist makes only $26,000, "that's all right. That's not a big penalty, and you get something for it." But if industry chemists are making $30,000 and university chemists are starting at $16,000, well, "nobody wants to sacrifice that much."

Consequently, Meisels says, starting salaries offered by major universities to chemists with fresh Ph.D.'s or with one or two years of postdoctoral experience have climbed substantially in the past four years. Typically, they are in the neighborhood of $20,000 for nine months. That corresponds to about $26,000 for 12 months, assuming that research grant support can be obtained for the summer. Meisels notes that many state universities will "guarantee the summer" for new faculty members the first year. Again, that usually isn't the case at smaller schools.

Like most chemical engineering departments, most chemistry departments are having trouble with equipment. For example, Gleb Mamantov, head of the University of Tennessee's chemistry department, observes that "it's paradoxical but true that we can, with NSF help, get something like a Fourier transform IR spectrometer or a state-of-the-art Raman spectrometer more easily than we can get something that costs only a few thousand dollars, but that we need for teaching.

"The equipment budget is totally inadequate," Mamantov says, "and it's very difficult for us to replace teaching equipment, like a new IR spectrometer for the junior lab, or a gas chromatograph—the routine stuff." He notes that in Tennessee's case, the problem is one of insufficient state funding. But except for a few elite institutions, private schools are having similar difficulties.

Mamantov concurs with others that it's not so easy to fill chemistry faculty vacancies as it was a few years ago, but that it's far from impossible. "We hired an analytical chemist last year," he notes. "The search was difficult, but we were able to fill the position with an outstanding person."

Lacking industry's money, chemistry and chemical engineering departments try to compete with other benefits. "Being near Oak Ridge National Laboratory," Mamantov says, "we've got something to offer that another department the same size might not have." He adds that eastern Tennessee is an exceedingly pleasant place in which to live.

Similarly, IIT's Wasan points out that IIT Research Institute and the Institute of Gas Technology, with their impressive facilities (and opportunities for consultant employment) are only a few doors away from his chemical engineering department, and that close cooperation is the rule. That proximity hasn't enabled him to hire any new faculty lately, Wasan admits, but he adds that it's helped him keep a couple.

Mamantov, like Meisels and Wasan, observes that money isn't everything, that there are compensations in university life. Echoing the recurring theme, he particularly cites "the ability to do what you want—if you can get the money to support it." When Mamantov came to the university after starting out in industry, he "took a really significant pay cut. It's hard, especially at first.

"But you know," Mamantov says, "you've just got to decide, yes, I want to teach and to be at a university, even if it means a sacrifice in money." Fortunately, he adds, "there are still some of those people left." □

Chemical engineering: a crisis

Professors and farmers have quite a lot in common. Both are highly productive. Both produce something vital to the welfare of society—the long-term welfare in the former case, shorter term in the latter. Both claim their efforts to be somewhat unrewarding financially. And both always seem to be facing a crisis of some kind.

With thoughts like these in mind, and with the healthy skepticism that is the mark of his trade as a journalist, C&EN's Chicago bureau head, Ward Worthy, has examined the state of chemical engineering and chemistry education in U.S. universities (page 43). He finds that rumors of a serious crisis in chemical engineering are indeed true. For chemistry the situation is not nearly so bad, but all is not right either.

In a nutshell, the chemical engineering profession is eating its seed corn. A huge demand from industry for chemical engineering talent and the relatively very high salaries that companies can pay are combining to make it very difficult for universities to compete with industry for the dwindling supply of new, high-caliber chemical engineering Ph.D.'s. In fact, established faculty members are being attracted into industry. And all this is happening at a time when the size of chemical engineering undergraduate classes has been skyrocketing.

To put some dimensions on the problem, between 1969 and 1977 an average of 3500 new B.S. chemical engineers were produced each year. During these years an average of about 376 new Ph.D. chemical engineers also were produced—about 11% of the B.S. level. By 1979, production of B.S.'s was up to 5655 whereas output of Ph.D.'s was only 304, just 5% of the B.S. level—and the large majority of these Ph.D.'s ended up in industry.

Compounding the problem for chemical engineering education is the obsolescence of equipment in university laboratories. Much of what is available apparently dates back to the 1950's. According to the American Society of Engineering Education, which has examined the whole engineering field, equipment for new "growth technologies" is almost nonexistent in university labs. This, combined with the chemical engineering faculty problem, obviously has critical implications for the caliber of engineering education, for the caliber of engineering research, and for the outlook for the creativity, innovativeness, and productivity of U.S. industry. The lack of state-of-the-art equipment also serves as another negative factor in trying to attract capable personnel to engineering faculties.

The crisis, if that is the right word, for chemistry is not nearly so severe. Nor can it yet be really quantified. There is a better supply and demand balance than in chemical engineering. Chemistry faculties are looking for more new people this year than at any time in the recent past. And if they look hard enough, and are patient, they generally can get good people. Industry demand for chemists remains quite strong. However, there seem to be subtle signs that the quality of chemistry education may be declining. There are feelings that the caliber of students going into chemistry, especially at the graduate level, is not so high as it once was.

If the present condition of chemical engineering is poor, and it is, the prognosis is, if anything, even poorer. State-supported schools likely will have to continue to struggle with restrictive budgets—and the likelihood of special funding to overcome the equipment problems appears vanishingly small. Private schools, in general, are certainly not awash with money. The federal government hasn't yet really come to grips with the problem—and with the current budget-cutting atmosphere in Washington it isn't likely to. There is considerable talk of more industry support for both chemical engineering and chemistry at the universities. But so far, in spite of some earnest efforts, this hasn't really amounted to any identifiable major gains.

It will be sad indeed if a long recession—with its subsequent decrease in industry's demand for chemical engineering talent—has to be the mechanism to stop chemical engineering from eating itself alive.

Michael Heylin
Editor

Views expressed on this page are those of the author only and not necessarily those of ACS

Mr. McCORMACK. The program of the National Science Foundation has been to upgrade the quality of education and retrain the faculty of junior high school through junior college, and even 4-year colleges, throughout this country. This is the thing we on the Science and Technology Committee fought for year after year: to maintain this program, to fund it to be certain that the quality of education in this country is maintained. The emphasis throughout this program has been on one thing, and that is on excellence—excellence in science and excellence in technology and engineering and mathematics. It has an extraordinarily high ratcheting power. The small amount of money that we put into this program affects the entire educational system because these faculty members, who may not have been the highest achievers in college, are constantly having an opportunity to improve the quality of their own education, and understanding of new technologies. They are refreshing themselves in an atmosphere where they can learn more and be better students themselves, and learn how to teach, and they are going back to their own schools and colleges to do so.

That is the great value of this program. It has a tremendous value symbolically, too, because it says that this country is sufficiently concerned about the quality of its education, that it will fund these programs.

I submit to you, Mr. Chairman, that if this program were to be discontinued, it would be a symbol to all the States saying: If you want quality education, provide it yourself without us, along with all the other things you have to provide as the budget is cut.

Finally, Mr. Chairman, I should emphasize that this will not be the first time that it has been necessary for the Congress and, indeed, for this Committee on Science and Technology to assume a leadership role with respect to policymaking. And this has been true for both Republican and Democratic administrations.

I point out to you that the Solar Heating and Cooling Demonstration Act and the solar omnibus bill were opposed by the administration, as were the Solar Photovoltaic Act and the geothermic energy law. The Electric Vehicle Act was passed over a Presidential veto. That was only one of two vetoes in the last 10 years that were overriden, and it originated in this committee. The automobile propulsion program that George Brown initiated, the conservation extension service, the breeder program and the new fusion law—all were either opposed or not supported by the administration.

These laws constitute the foundations for our energy programs for today and tomorrow.

It is important to remember that you do not have to turn to the administration in all cases for leadership. Congress does have an equal role. As much as I respect the administration for its attempts to balance the budget, there is not today a single scientist anywhere in the higher echelons of the administration—not in the White House, not in the Office of Management and Budget, not a single scientist anywhere in policymaking apparatus of the new administration. I know this will be corrected in the future, but the policies that are coming up to you today have been made by well-intentioned individuals who simply did not understand the implications of what they are doing or recommending in such instances as this.

Finally, this is no one person's, or no one group's, or no one State's, or no one profession's sacred cow. Education is everybody's business. We all have direct involvement and interest in it, and I respectfully submit that this committee must once again in this case assume leadership, and set wise policies for our Nation.

Thank you, Mr. Chairman.

Mr. **WALGREN**. Thank you very much, Mr. McCormack. We certainly appreciate your guidance in this area particularly in view of your own background.

The Chair would like to recognize the chairman of the full Committee on Science and Technology, Mr. Fuqua of Florida.

Do you have any thoughts you would like to give us at this point?

Mr. **FUQUA**. I would like to express to Mike appreciation for your being here and talking to us. I certainly agree with all that you have said.

It is a very important area. I think earlier our chairman cited some statistics related to the problems, and you have gone over those of science and engineering education. I have been extremely interested and concerned about what I see as a potentially disastrous situation.

Without being excessively alarmist, I would note that the Soviets have accelerated all of their science and engineering programs. They are turning out a million technical specialists from secondary schools annually. We have no comparable program of that type in this country. The Foundation's traineeships and fellowships must be considered as a key element, I think, in addressing our long-term science and engineering manpower needs. These need to reside in an Education Directorate now slated for elimination, and there are many other problems in the list that have already been mentioned by you and some of the other witnesses that will be here today.

There is a serious lag in instrumentation for research and development in our universities. The Foundation in its own analysis for mathematics and the physical sciences showed $2 billion needed over the next 5 years in that one directorate alone.

There is also an obvious connection between the quality of our scientific and technical research and the eventual translation of that knowledge for competitiveness into the marketplace. There is proposed a 60-percent reduction in the international science program, a program with serious implications for our U.S. foreign policy as well as the scientific community, as our competitiveness in the international market area is going to depend on the flow of information supported by many of these programs. I think we must be very careful in trying to solve our country's economic problems of today, and I surely hope we do not slam the door on resolving our problems of tomorrow, while we are solving those of today. Thank you for being here, Mike.

Mr. **MCCORMACK**. Thank you, Mr. Fuqua.

Mr. **WALGREN**. Are there other members with questions?

I want to apologize to Mr. McCormack, the next witness is under a very strict time deadline with us of 3 o'clock, I understand.

If there are questions, let us keep them relatively brief or make ourselves available to Mr. McCormack personally.

Mr. McCormack. I will be available to answer questions in the future.

I will be on the Hill.

Mr. Walgren. Well, thank you very much, Mr. McCormack. We surely appreciate your being with us.

It is my very real pleasure to introduce to the committee and the audience one of the reasons I think some of the audience is here today, Dr. Carl Sagan, our next witness.

Dr. Sagan is perhaps best known as the narrator of the televison series "COSMOS," but he has certainly caught the imagination of America in turning our attention to science and the discipline of science, and the direction of the mind and the intrigue of the areas to which it could lead us.

He is a popular author, having written a number of books, including "The Dragons of Eden," but professionally is more strictly known as a professor of astronomy at Cornell University. I would like to welcome you to the committee, Dr. Sagan, and I would only comment further that I had the opportunity to be at the presentation you made to another body of Congressmen the other evening. I am struck as I look around this room at the pictures on the wall, with what you said about the only historically significant event or contribution that mankind is making to history, that we have left the force of gravity and are at least on the way to opening up other worlds.

You have done a great deal to urge us on in that direction, and I personally want to express the appreciation that so many people whose minds you have intrigued have for you. Welcome to the committee, and we would appreciate your views in the area that we are pursuing today.

STATEMENT OF DR. CARL SAGAN, PROFESSOR OF ASTRONOMY, CORNELL UNIVERSITY

Dr. Sagan. Thank you very much for your extremely kind remarks. I would like to make a reasonably brief statement, and then try to answer any questions which the committee members may have.

Let me start by asking you to imagine yourselves somewhere in the middle of the 19th century with the idea that it would be nice, for whatever reason, to have a box in every home, and in that box would be a moving picture which would instantaneously appear there from some distant transmitting station.

It would clearly be useful educationally, politically, and perhaps even economically. Suppose you had an idea that you would like to have this magical device which today we call television.

Given the science of the 19th century, how would you go about it?

The simple answer is there would have been no way to go about it. The level of scientific advance in the middle of the 19th century was simply inadequate to develop television technology—or radio or a whole set of associated technologies.

But at just that moment in the midst of the 19th century, a Scottish physicist named James Clerk Maxwell was fiddling with some mathematical equations. He did not like their asymmetry. He looked at these four equations, which were based on some experiments that French and English scientists had done, and they didn't look right to him. They did not look pretty. So, on the basis of a purely esthetic judgment, he added one term to one of the four equations in order to make the equations look nice. That step, that term is called the displacement current, and that intuition of Maxwell's, that there was a term missing in these equations, led him to predict electromagnetic waves—the fundamental insight on which television is based.

My point is that it is very hard to tell where fundamental science is going to lead, and it is very hard to lead technology very far into the future.

This example is one of hundreds, which any scientist could provide, on how fundamental discoveries of the greatest practical importance have come from apparently unrelated scientific fiddling. Of course, not everything that every scientist wants to do has to be supported. Clearly, there has to be a limit on what is an acceptable amount of money for the support of science. But at the same time it is very important to remember that support of fundamental science is the aperture to the future. It is the way to guarantee that there will be future advances.

The National Science Foundation has been for many years the primary source of support for American science, and has done a superb job, in my opinion, across the board in virtually all areas of science within its domain.

I would like to urge on the committee, I know this must be a familiar story to many of you, the importance of supporting, even at a time of severe budget crunch, fundamental science which has no immediate apparent practical benefit.

There are short-term objectives, and there are long-term objectives, and no amount of solving the short-term problems will guarantee that we will survive the long-term problems. We must simultaneously attack both short- and long-term problems. Science is the method for doing this.

Now, in addition to the support of fundamental research itself, the National Science Foundation has been a leader in supporting science education.

I would like to say something about the importance of science education. First of all, it provides the next generation of scientists, and at least for the most brilliant discoveries, the cycling time of scientists is short. In mathematics and some of the physical sciences, the most brilliant discoveries are oftentimes made by people in their twenties or thirties. It is a short generation time, which means the importance of supporting young scientists may be greater than the importance of supporting young practitioners of other professions.

Science education is also vital for the older generation of scientists. Someone like myself, who does both research and teaching, finds that each aids the other. Not only do I teach better if I do research, so that the latest discoveries can be cycled past the students, but perhaps more important, the necessity of teaching the students encourages my own reexamination of the fundamental underpinnings of the science. It is a two-way street. Graduate students in science have made extremely important contributions, sometimes not fully acknowledged, to the progress of many kinds of scientific research.

It is not a luxury, the teaching of science. It is essential, as I said, for the next generation of scientists but also for keeping very alert and on our toes the present generation of scientists.

We live in a society which is clearly dominated by science and technology. Many of the aspects of our everyday life which make life pleasant, although by no means all, are traceable to science and technology. It is also very clear that many of the problems which face us are traceable to science and technology. But there is no conceivable solution to those problems that is independent of science and technology.

If we have problems with pollution, let us say, or the threat of nuclear war, there is no conceivable solution to those problems which does not involve in a fundamental way the same science and technology which has brought us face to face with those problems.

I do not think it is an exaggeration to say that our national survival, or even our survival as a species, depends on how well we understand and perform science and technology.

But at the same time there is a clear crisis in this country in that the level of scientific literacy is remarkably low. I would like to echo the remarks of Mike McCormack who preceded me as a witness: American public school education in science is abysmally poor by absolute standards, and certainly by comparison with the sorts of curricula one can find in the Japanese or Soviet or East German educational systems. Not only does that threaten this next vital generation of scientists, but also it means that the public at large is unable to make or is at least under some difficulty in making the kinds of decisions about science and technology which we require in a democracy. How can people who do not understand what molecules are make fundamental contributions to deciding on issues about industrial pollution, to take one example?

In a democracy it seems to me we have a particular responsibility that the tools for dealing with the problems that face us be widely available.

Our COSMOS television series has been the most widely watched series in the history of public television. Our experience is that there is a vast hunger for scientific information in the general public, that people recognize the excitement of science, the fun of it, the way it approaches fundamental questions about the nature of the world which human beings have always been interested in. People recognize that they do not have as much background as they would like in the sciences.

The thousands of letters that we have received following the first showing of COSMOS has convinced me that there is an enormous number of people in the country, in every congressional district, both sexes, the entire spectrum of ages and ethnic groups who are bright, interested, articulate, and simply have not been exposed to as much science as they want.

There are many other lines of evidence supporting this; for example, the rash of recent popular magazines devoted to science. There are something like six of them with circulations in the hundreds of thousands, and it is a remarkable fact that every time a new one appears, the circulation of the old ones goes up.

The market is certainly not saturated in popular science.

The role of the National Science Foundation in communicating to the general public what science is about is another very important aspect of the NSF, and I would like to urge that such programs be retained, and even expanded.

There are many lines of evidence that the public will support the doing of science and will support the communication of science, and it is very clear that it is essential for the protection and enhancement of the American industrial economy, the pursuit of technological innovation, in which the United States has been a historic leader. I believe that were the United States to surrender such a role, it would be a danger not just to the United States—in a competitive position with other nations—but, because of the great U.S. contribution to world science, it would be a danger to the planet as a whole.

Mr. WALGREN. Thank you very much for sketching it out for us on that scale. The Chair would like to recognize the ranking minority member, Mrs. Heckler from Massachusetts.

Mrs. HECKLER. Thank you, Mr. Chairman. I must say that it is a pleasure to listen to your analysis. I share your concerns. I wonder, if you were asked to articulate the bottom line, as we say in Washington, in terms of the promotion of scientific understanding by acceleration of the development of trained professionals in the field, and the development of more scientific literature in the body politic as a whole, what would be the essential ingredients of that program? What is the bottom line in order to achieve the goal in terms of the leadership that we must have in the world, in terms of our own country's needs?

Dr. SAGAN. I would certainly suggest that the National Science Foundation budget in these areas not be cut. If anything, I think it should be increased.

I also cannot help but think more Members of Congress with scientific backgrounds like Mike McCormack might be useful. I realize he is an example of a trend in the other direction. I do not mean that as a political comment.

Mrs. HECKLER. Did you campaign in his district?

Dr. SAGAN. No; perhaps I should have.

It is really quite important that there be scientifically knowledgeable Members of Congress and people in the executive branch. Just to give an example about the executive branch this morning, I have been over at NASA headquarters at a meeting of the Space Science Advisory Committee, and they are under some serious strains also, as you might imagine. It is pretty striking that there is no one to talk to. There is no Presidential science adviser. There is no NASA administrator, no associate administrator for space science, and no director of planetary programs. Perhaps this is an oversight which will be soon rectified.

I would say that the greatest possible encouragement by both Houses of Congress and the administration for scientific literacy in the general public; for the production and encouragement of young people interested in professional careers in science; and for continuing the historic American tradition of support for basic research are the fundamentals of our continuance as a major scientific power.

Mrs. HECKLER. Doctor, I could well understand your perceptions as you have made your visits. However, I think that personnel changes and personnel appointments are going to be of high caliber and likely to be forthcoming in the near future. I would expect that to be the case and hope that is indeed a true statement.

Would you say then that you would not support any cuts whatsoever in terms of the budget?

Dr. SAGAN. I realize this must be a heterodox opinion; but I would urge in fundamental research, in the support of general scientific literacy and in the support of science education, an increase in the NSF budget.

I believe the level of support for these programs in the recent past has been if anything dangerously low.

Mrs. HECKLER. Thank you very much.

Mr. WALGREN. Thank you, Mrs. Heckler. The Chair would recognize Mr. Fuqua, the chairman of the full committee.

Mr. FUQUA. Thank you, Mr. Chairman. Carl, we are happy to have you before our committee once again. You have been before various subcommittees and the full committee on numerous occasions in the past. You always bring great enlightenment and we are happy to have you.

I want to say that we deeply appreciate the work that you have been doing in science enlightenment. As you also mention in your statement, there have emerged numerous new periodicals on science that have shown great imagination, which leads me to believe that a vast number of people are craving some type of knowledge about science. The problem is how can we present science to them in a fashion, so that they can better understand it and realize the fruits of science and what it can do for humanity.

I want to comment to you on the great job that you do in articulating science to the public, because you help make our job a lot easier in trying to understand and appreciate the benefits of science, particularly basic science. I thought you explained it very well, the importance of it, what it means in the long run. I do not think any scientist really sits down and says this is what I am going to find at the end. Many times, many avenues branch off of that road that lead to discoveries that no one ever dreamed would happen, so I thank you for being here and I am sorry I missed you the other night. I was trying to promote science in another city.

Dr. SAGAN. Thank you very much.

I believe that the popular support for science has been misread, that it is enormous, and if I may say so, that it is politically a good idea to support science, even if it were undesirable on other grounds.

I know there have been perceptions that the support of fundamental science will be misunderstood as just giving expensive toys to a few scientists who do not count much as far as votes go. By and large, I think that people hunger to understand the world they live in, and to master the tools for surviving the future. That is what science is about.

Presented that way, I believe even the most esoteric kind of research can be understood and supported.

Just yesterday, the newspapers featured an announcment of research supported by the NFS done by Dr. Hyron Spinrad of the University of California, in which a set of galaxies was calibrated as being something like 10 billion light-years away, more than half way to the horizon of the universe, looking back in time more than half-way to the epoch in which the universe, or at least its most recent incarnation, began.

That story was big news. Why was it big news? Because people recognized that here is an approach to fundamental questions, to issues of the origin of the universe, There is no human in any culture that has ever been on the planet Earth that has not wondered about that question. Those sorts of questions are as natural as breathing. They are what humans are about. That kind of science is in a way the secret of our success, wondering about things, pursuing them, finding out how the world works.

I believe financing fundamental science, and applied science is enormously popular.

Mr. WALGREN. Thank you, Mr. Fuqua.

The Chair would recognize first Mr. Brown, the former chairman of this subcommittee, and then members alternating from side to side in the order of their appearance.

Mr. Brown.

Mr. BROWN. You are very generous since I came late. Let me ask one question. The importance of science education would not be denied by most Members of Congress, even though they might vote against the budget for the Science Foundation. I think the fundamental question that we need to explore is what is the mode by which science literacy can best be developed. The basic responsibility, of course, is with local school districts, with the Foundation serving as a standard of excellence, as an aid in developing the best possible programs. My question to you is, do you see the enhancement of the level of scientific literacy improving, or getting worse at the present time in light of the developments that you have referred to of programs such as your own, and of the burgeoning science literature aimed at popular audiences? To you does this not indicate a growing level of scientific sophistication or literacy, or does it seem to you to indicate the opposite?

Dr. SAGAN. It indicates to me an unsatisfied hunger.

I have often said about COSMOS that if, after seeing 13 episodes, a viewer left without remembering a single fact, but with a newfound sense that science is interesting and accessible, I would be perfectly happy.

I think that the success of programs like COSMOS and the burgeoning magazines that we have referred to certainly demonstrate that people are interested in science, but they do not demonstrate that people are learning the fundamental science which is their birthright and is essential in a democracy based on science and technology. That can only happen by much deeper study than glancing through a magazine once a month. I could see that happening, for example, in cable televison courses for adults, in adult education classes, in community colleges. But fundamentally it requires education in the public schools. Certainly you are right that education is traditionally and fundamentally a responsibility of the States. But the Federal Government has historically played, and in this case, certainly can continue to play a major role in setting tone and direction, and in encouraging schools, for example, to have the courage to do some serious and perhaps difficult mathematics or sciences.

Another question has to do with the scientific literacy of teachers. There are some friends from the National Association of Science Teachers here, and there is no question that there are many superb science teachers in the American school system. But I also must say—this is only anecdotal, but deeply felt—that there are many teachers who are not extremely good. Programs to develop the scientific literacy of the teachers and their ability to teach are equally important.

Mr. BROWN. Well, frankly I am struggling to find ways in which I can accommodate myself to what I feel are the laudable goals of this administration to bring about some solutions to economic problems, without losing the base of progress which we are making in this country. If there were alternatives to spending money, such as, for example, better leadership or an improved vision of what a scientifically competent society would be, and we could do that without money, I would like to do that. But I confess that I have not quite figured out what the mechanics of that would be.

Dr. SAGAN. Maybe a weekly fireside lecture by the President on a scientific topic.

Mr. BROWN. Or someone who would substitute for him for that lecture and give him help. If you come up with any good suggestions that do not involve any money, I would like to have them.

Dr. SAGAN. I will think on it. However at least as far as I can see, there is no way to do this without spending some money; but the National Science Foundation budget is really tiny compared to the overall Federal budget, one-tenth of 1 percent.

It seems to me that it is possible to pursue some budget cutting goals in a serious way and still spend enough money to protect the future.

Mr. BROWN. Thank you very much.

Mr. WALGREN. Thank you, Mr. Brown.

Mrs. Schneider from Rhode Island.

Mrs. SCHNEIDER. No questions at this time.

Mr. WALGREN. I hope that Members take the chance to raise questions with Dr. Sagan. He will have to leave shortly, I know, and so if we are quick, we will get through.

Mr. Ertel.

Mr. ERTEL. Thank you, Mr. Chairman. Dr. Sagan, just to enlighten you a little bit. I had dinner with a chap Saturday night who covers the Defense Department for one of the leading newspapers in the United States. And he advised me that what you observed of your scientific endeavors here in Washington is also true of the Defense Department, that in fact they do not have people on board who are running the program at the present time. So I think what you have seen is something symptomatic of the time we are in right now and not necessarily a slight at just the scientific community. I do not know if that helps put it in perspective or not.

You have used the term scientific literacy. There seems to be an assumption that if people have some knowledge of science it will foster an indepth knowledge of basic science, just by the fact that they have the scientific literacy or at least exposure to it.

Do you feel that because people are just exposed to science, that they will then follow through and more people will have indepth knowledge and therefore pursue scientific evidence much more diligently?

Dr. SAGAN. I imagine a youngster growing up in a home where the parents, through no fault of their own, simply know nothing about science. Contrast that with a home in which the parents have a passing knowledge, a familiarity with scientific ideas. That second child is at least able to be pointed to some scientific books.

His questions are encouraged. It is a very important difference.

Kids start out as natural scientists. "Hey, mom, why is grass green?" The parent who does not know anything about science is to some extent put on the defensive by such a question and might answer, "Don't ask dumb questions."

You try that a few times as a youngster, and you keep being told "Don't ask dumb questions," you learn that adults dislike that kind of question. A part of your mind turns off, the scientific part. In contrast parents who know even a little science might say, "I think there is a molecule called chlorophyll, but I don't know how it works." That's still a superficial answer, but it's much better. Or the parent might merely say, "I don't know why." Or a more literate parent might answer, "The fundamental reason that plants are green is still a mystery. Nobody knows. Maybe when you grow up, you'll find out."

It seems to me there is a world of difference between those two situations. You do not have to be a scientist in order to encourage youngsters in science.

Even passing familiarity with scientific ideas is extremely helpful, if you have to vote in a local election where a nuclear powerplant is an issue on the ballot, or pollution, or abortion or where you have to decide between two candidates with differing postures on nuclear war.

In every one of those cases, it is certainly helpful to understand something of the science. It just makes for better democracy.

Mr. ERTEL. I understand your point of view and appreciate it, but there is an old platitude, I guess, "A little knowledge can be a dangerous thing," and I am wondering sometimes with superficial knowledge, if we do not in fact discourage some people by not having the right answer. But really I am trying to get at how do we develop, rather than the superficial interest in science, the indepth interest which will promote scientific endeavors in the future among out students and get them encouraged to follow a scientific pursuit? I would agree with you having some knowledge, generalized knowledge certainly would help, but how do you go beyond that, to really strike at the real problem, which I think in this country is to get people to follow scientific pursuits in a meaningful way.

Dr. SAGAN. I think there are two prongs to that attack.

One is to communicate the idea that it's OK to do science, that it's not an activity of socially backward people in white coats who lock themselves up in labs, that science is human, indeed a joyous adventure, that it's fun. This can be done, as Congressman Brown was hoping for, with very little money. But the other prong of the attack is to have adequate, indepth education in science at all levels in the public schools, and in the universities, especially in major research universities. That does take some money. Making the pursuit of scientific careers socially acceptable for youngsters, and then providing the means for them to learn science in the schools is the way to do it.

Mr. WALGREN. Thank you very much.

Mr. WEBER. I would like to probe a little bit more on the school subject. I recognize your feeling that the scientific education that we are giving—primarily I am thinking in terms of elementary and secondary schools—is inadequate. I wonder if you can explore that a little bit more. Do you feel that it is primarily that students at that level are not being exposed to enough scientific education, or that the scientific education they are receiving is inadequate?

Dr. SAGAN. Both. One aspect which is on my mind these days is in biology. The teaching of evolution, which is the fundamental insight that unlies all of modern biology, is being done at an extremely cautious and tentative pace because of an assault on the teaching of evolution by people who call themselves "creationists." This caution is widespread not just in States where there have been laws or recommendations passed on it, but in many other States where teachers just don't want to get involved. There are many States in which in the 1 year of biology, which is all that is mandated, there is 1 day of tangential approach to Darwinian evolution. Biology is a particular kind of science which is in trouble for a peculiar kind of reason that does not apply to, say, chemistry or physics. But the next generation of American biologists is in real danger.

Consider the technological future of genetic engineering, for example, which I consider to be of enormous importance and of the greatest practical value. Who are the people who are going to be working in that field in the future, to design microbes to clean up oil spills and to produce large quantities of molecules which might be useful in treating human diseases? They must be people who are comfortable with molecules and evolutionary biology. But if modern biology is not being taught in the schools, if children are being told to be extremely cautious, "Don't believe your teacher on this issue," we are carving ourselves a very dangerous future.

Now, on questions like physics and chemistry, 10 or 15 years ago it at least was usual to have a year of physics and a year of chemistry as part of the curriculum for students in academic programs who didn't necessarily intend to become scientists. That is no longer the case. Also, courses in earth sciences or astronomy, which are common in Europe and the Soviet Union, are almost unheard of in the American school system.

Mr. WEBER. If I can continue on that point——

Dr. SAGAN. Please.

Mr. WEBER. The point I am getting at, if the question is not the competency or at least not entirely the competency of the teachers but the amount of education they are giving on scientific matters, to come down to a simple time problem, I think very few people who have a constraint about education would support trading off time in English, for instance, for a science. I mean, indeed, of the time that is devoted in a school system to any given area, the area of increase has been in behavioral science primarily or that type of thing. It seems to me if we are going to enhance the role of science in our school system, it is going to diminish something else, and probably it would be the behavioral sciences that are exploding somewhat. How would you feel about that?

Dr. SAGAN. That would be an awkward choice to have to make.

Mr. WEBER. Do you think a choice is necessary?

Dr. SAGAN. I would hope not. I certainly agree with you that literacy in a language is probably even more important than literacy in science. If people don't know how to write and speak and read, it is very unlikely they are going to learn to do science as well.

But again I look at the educational systems of other countries, and I see places where 12 years of mathematics and 3 years of physics, and 2 years of chemistry are all part of the usual curriculum for people who are not going to be scientists. They also learn their native languages and usually one or two other languages at least middling well. The answer may be more efficient teaching; it may be longer school hours; it may be better support for teachers so they are willing to spend time after school, at least with promising students. It seems to me there are many different approaches which could be creatively pursued.

Mr. WEBER. In order to do that we must not diminish the importance of sustained or increased funding, but in addition there are probably needed some institutional changes in scientific education in this country.

Dr. SAGAN. I think that's right, but I think that would follow naturally from a general perception that it is important to learn, that learning is the way to insure our individual and national and global futures. I believe people are fundamentally bright in every economic class in the Nation, and if that acceptability were generally understood and encouraged, you would find kids flocking to such classes, volunteering to stay for 1 hour after school. Science is exciting, and there are all sorts of experiences of youngsters wishing to spend time on their own to pursue science if it is presented in even a moderately interesting way. I think it can be done.

Mr. WEBER. I agree with that. Thank you for coming here today.

Mr. WALGREN. Thank you, Mr. Weber.

Mr. Shamansky.

Mr. SHAMANSKY. Dr. Sagan, I am also on the International Economic Policy and Trade Subcommittee of the Foreign Affairs Committee, and I am especially concerned about the science and mathematics education of American school children as contrasted with Japanese, Western European, Eastern European, and Russian. I don't know whether you feel qualified, but I hope you do, and I wish you would give us a brief survey of your opinion on these matters.

Dr. SAGAN. Well, I would not call myself very qualified, but I have read, for example, the report of Itzsaak Wirzsup, professor of mathematics at the University of Chicago, who has recently done a study of mathematics and to some extent science in the Soviet school system. I know a little, from a recent visit, about the Japanese educational system. I would say it is very clear that the general level of scientific literacy in the schools in all of the regions of the world you have mentioned is substantially greater than it is in the United States. That superiority will get converted in whatever the time scale is—10 years, something like that—into greater industrial productivity, greater technological innovation, greater ability to use science and technology for national interests in those other countries than here.

There are very few predictions about the future that I consider reliable, but I think it is extremely clear that if there is a fundamental tool for the future called science and technology and we are not teaching or using it, we are going to be in trouble in the future.

Mr. **Shamansky**. Has the science and technology community made that view known to the industries that take its graduates?

Dr. **Sagan**. Well, perhaps not as vigorously as we should have. I might also say that, for example, in the Soviet Union there are elementary and secondary school textbooks written by research scientists of the absolute highest caliber. That is not the case in the United States. Generally speaking, the textbooks are done by competent people, but not the most brilliant, not the most inspiring, not the very best; and so in these two respects I think we scientists have not done as much as we should have. But I can remember some distinguished scientist complaining that because he didn't have the appropriate secondary school credentials, he could not voluntarily teach in the high schools as he wished. He was not considered qualified by the school system.

The question of industrial support for fundamental science is a very interesting one, and maybe some progress could be made there; although I don't know to what extent American industry would be prepared to support fundamental science where the return to the industry would not be guaranteed, and might in any case be a decade or two away. But it is certainly worth pursuing.

Mr. **Shamansky**. Thank you, Mr. Chairman.

Mr. **Walgren**. The next would be Mr. Hall.

Mr. **Hall**. Yes. I just have one brief question. You alluded to an age cycle for scientific achievement, and you said that it was quite young. Do you have an age, a year in there?

Dr. **Sagan**. Well, it depends on the particular science. There are many notable exceptions, but, nevertheless, there is a tendency for the most striking advances in fundamental mathematics and in theoretical physics, to take two examples, to be made by people in their twenties and early thirties.

In experimental sciences, this is not so much the case at all, and here fundamental discoveries are made by people of all ages. Even in theoretical studies, there are great contributions being made by people in their sixties and seventies. But more than in any other fields, fundamental theoretical advances are made by young people in physics and mathematics. That means that if you have a 10-year period in which you are not supporting fundamental science, you can lose a generation.

So it is not a case where we can say, well, we have particular problems right now; we'll wait until 1990 and then fix things up. You may not be able to fix things up in 1990.

Mr. **Hall**. Thank you.

Mr. **Walgren**. Mr. Gregg.

Mr. **Gregg**. I have no questions, Mr. Chairman

Mr. WALGREN. Mr. Dymally.

Mr. DYMALLY. Dr. Sagan, in terms of the community colleges, many of which are located in central cities, do you see a need for increasing science education?

Dr. SAGAN. I certainly do. As I said before, I find the level of scientific interest and ability very widely distributed in the American population, and I believe there are communities especially in the central cities where there are very bright and promising youngsters who, due to the lack of opportunity and lack of exposure to scientific ideas at an early age, are lost to science. It would be very useful to have science presented in such schools, even if the objective is not this generation but the next one: The children of those youngsters in those central city schools would then be raised in an environment where they would be encouraged to pursue science, and we would see significant scientific contributions from that next generation.

Mr. DYMALLY. Thank you, Mr. Sagan.

Mr. WALGREN. Mr. Lundine.

Mr. LUNDINE. I have one brief comment on that. I come from Jamestown in upstate New York, and it has been interesting there to witness a program they started called science and the citizen in the community college. It is very interesting to watch people of all age groups taking that—students who are going to pursue further education as well as career students and senior citizens from the community coming in and taking the course.

Dr. SAGAN. Yes.

Mr. LUNDINE. Now I have a question, briefly. Other than the science education, have you concerns about Federal policies that serve as barriers to innovation, in other words, the process of getting from the basic research to the payoff in terms of productivity? Does that seem one that is unnecessarily clogging?

Dr. SAGAN. To some extent. First of all, it is a very important question. I have perhaps one small point, but it is from my personal experience. The amount of time that research scientists have to spend in preparing grant proposals and in justifying them has grown steadily over the last 5 or 10 years. Now we spend a major amount of time trying to get the scientific support, and there is a decline in scientific productivity per dollar as a result.

I understand the reasons for accountability, and I understand that bureaucrats want to be protected against the possibility that someone spends the money to go on a vacation to Buenos Aires; but the likelihood of such abuses in the scientific community is small. (In fact one fundamental discovery in mathematics was made on the beach at Buenos Aires.)

I would think that at least for established investigators, less concern about paperwork and accountability, and a longer continuity of guaranteed funding support would be a useful innovation.

On the question of the conversion of scientific discoveries in fundamental science to practical matters, that is often a temperamental question. Very often scientists interested in fundamental discoveries are not interested in their application. On the other hand, there are many people, including many in industry, very interested in applications. So it's necessary that there be better communications between people of different scientific temperaments.

Mr. LUNDINE. Thank you.

Mr. WALGREN. Thank you, Mr. Lundine.

On behalf of the committee, I want to thank you very much, Dr. Sagan, for underscoring your perspectives by your presence here.

The committee will take a 3 minute recess to shift witnesses, and we will convene very shortly.

Dr. SAGAN. Thank you, Mr. Chairman.

[Whereupon a short recess was taken.]

Mr. WALGREN. The committee will come to order. The next witness is Dr. Guyford Stever. Dr. Stever has had a distinguished career as a scientist, engineer, educator, and administrator. He currently serves as chairman of the Assembly of Engineering of the National Research Council, and is a corporate director, trustee, and consultant to industries, universities, and government. I want to welcome you to the committee, Dr. Stever. We appreciate your background and look forward to what light you can shed on your future course.

[A biographical sketch of Dr. Stever follows:]

DR. H. GUYFORD STEVER

SUMMARY

Dr. H. Guyford Stever has had a distinguished career as a scientist, engineer, educator and administrator. He currently serves as Chairman of the Assembly of Engineering of the National Research Council, and is a corporate director, trustee and consultant to industries, universities and government. Among his directorships are those of TRW, Inc., Schering-Plough Corporation, and Goodyear Tire Company.

He served in 1976 and 1977 as White House Science and Technology Advisor to President Ford, Director of the Office of Science and Technology Policy, and as a member of the President's Committee on Science and Technology. From 1972 to 1976 he was both Director of the National Science Foundation and Science Advisor to the President.

STATEMENT OF DR. H. GUYFORD STEVER, CHAIRMAN, ASSEMBLY OF ENGINEERING, NATIONAL RESEARCH COUNCIL, NATIONAL ACADEMY OF SCIENCES, NATIONAL ACADEMY OF ENGINEERING, AND FORMER DIRECTOR OF NATIONAL SCIENCE FOUNDATION AND SCIENCE ADVISER TO PRESIDENTS NIXON AND FORD

Dr. STEVER. Mr. Chairman and members of the committee, I am pleased and honored to be invited to testify today. I have some written testimony which I would like to enter into your record with one or two corrections and improvements.

Mr. WALGREN. Without objection, any statement you would like to submit will be made part of the record in full.

Dr. STEVER. I would like to summarize a few points. It is a little difficult to testify after the appearance of great leaders in science. If anyone thinks we aren't doing well in the public understanding of science, they should listen to those leaders. They are the very proof that we are winning in that game in this country.

Over the past decades this country has established a very strong science and technology program, which has been fed by a university educational system that has been very effective. When we talk of the problems we are facing today, let us make sure we understand that we are on a firm basis.

There is an old Russian peasant saying that one should never throw away the old water until he gets the new. We should not cast aside this powerful system we have constructed, or hack away at it, until we are sure that we have found a way to continue to grow in quality as we change.

Naturally, with the background you just read, you will recognize me as a lover of the National Science Foundation and one who has great respect for it as well as for a number of other government institutions which have supported our powerful science and technology base.

The National Science Foundation is clearly under attack, as are all agencies of government. My testimony didn't take up all of the rumors we hear about this, but I know that some members have inside information, and it looks quite frightening. I have, as I have gone through this tried to pick on a number of the specific problems that are emerging to see if there are different ways of handling things, or if we must continue to lean on what we now have.

In the previous testimony you have heard a mixture of the problems of quantity and the quality of the output of the science and engineering education program. The National Science Foundation and other organizations have recently issued a report that says we won't face a long-term numbers supply problem. I am not quite sure I agree with this, and I know a number of other people don't. It really depends on whether this country attacks the science and technology problems it is facing with the vigor that Carl Sagan and Mike McCormack have just urged.

I don't think there are many people who believe that we don't need to use all of the science and technology we can muster to tackle some of the problems in front of us. If we do, we may find that the recent conclusions that we don't need more, particularly more engineers, may be wrong. But even so, if we just assume that the long-term problem is one of maintaining quality and growing strength, there is a short-term problem which is a numbers problem.

There are lots of shortages, in engineering particularly, and in some fields of science. It is not hard to see where. There is the rapidly growing field of the information sciences, involving computers and communications. There is the field of energy technology needed to improve our industrial productivity. There are many kinds of engineers, and some scientists, that are very much in demand. Those industries that I am associated with, and lots of others that I deal with, are beginning to get their own individual programs to make sure that they get their fair share of the output of manufacturing engineers in the future. That doesn't mean just any engineer; they want quality ones as well.

Can we attack the problems that were outlined by Mike McCormack: the shortage of 2,000 engineers in the universities brought about probably because the universities cannot pay them highly enough in competition with industry? The research environment in the university is getting tougher and the teaching loads are getting bigger for engineers and some scientists, and that means they don't have as much time to do the research and other important jobs. In addition, the task of soliciting research grants to pay for expensive research is tougher. I don't think this can be quickly stopped, and I suspect that we are going to have to fill some of these short-term shortages with some stopgap means.

Industry itself can do a lot. Most people don't realize what a powerful educational system there is in our larger industrial, high technology corporations. Most of them are capable of giving courses. They have lots of talent on their own staff. They can educate their own people and upgrade them to the jobs they have. In the long run, it is an unsatisfactory solution not to have the right balance of fields of endeavor, fields of expertise, nor the right balance with respect to bachelor's, master's and doctor's levels.

Currently large numbers of engineers and quite a few scientists are leaving at the bachelor's level to go to work at high pay. That way they are not reaching their full educational potential. I think that we have got to find ways to bring the universities back to strength so that they can stand up in the competition for good people. The industries are going to have to recognize that they have part of the burden to help those universities do that.

Industries are very anxious today to establish relationships with universities across the board for several reasons. The universities are more receptive. The universities were sent away from industry after World War II, and the scientists and engineering programs at the universities were drawn over to government-oriented needs and government-supplied funds. Universities and industry grew apart.

Today universities recognize they need the help of industry. They need money. They are being criticized because they aren't turning out the right people for our total technological society. The industries are coming back, and they are realizing how dependent their future is in many fields on the universities. That is a problem growing in our country, and we should know it.

Some people will say that we will solve our problem. We can shift to the kind of support of science and engineering that industry will now provide. I don't believe that. First of all, even if the industries do their utmost in this, it will be primarily aimed at engineering—and that is important—but the sciences which are equally important will not get as much of that input.

Also industry just doesn't have that many resources to put into this kind of thing. There is a profit squeeze in industry. Maybe with good times coming again one day they can afford more of this, but I do not see that they can make that substitution quickly.

The lack of qualified teachers hurts more than just the universities. If the universities can't get teachers, the high schools can't get them either, so the pool is decreasing.

I am very glad that Carl Sagan mentioned that there are many very fine, dedicated high school teachers who are inspiring and turning out lots of very good products. My colleagues in the university world think they are getting some of the best people ever, so we may find the average of the product of high schools decreasing because lots of people don't take any engineering, science or mathematics; but those who are dedicated to it, those who are picked out by the good teachers are in fact coming along very well.

Any of you who attended the Westinghouse science program last night and saw those 40 winners from all over the country, bringing their research programs to demonstrate, will recognize the tremendous excitement that lots of young people do have.

But the secondary schools are having a tough time.

We talked a little bit about the public understanding of science. I would like to say right off that in my 40 years in the science and technology field, the public understanding has grown tremendously in the Congress and in the community generally. You can't pinpoint any one thing, although again television is one of the most powerful tools of today, and I think that it will grow more powerful in giving a better public understanding of science.

There is another thing. Necessity has brought on a better understanding of science. Science and technology are now so powerful that they are too important to be left just to the scientists and engineers. Lots of advances in those fields can have a tremendous impact on all of our lives in all aspects. If the leaders throughout our society don't understand what they can do to harness them for the good, and how to hold back the problem areas, we cannot get along. Our leaders have been responding to that. They do pay more attention these days.

We have talked a little bit about the problem of so many foreign students in our graduate schools. I would like to see a better balance, but I have to say that one of the very important reasons the United States science and technology is so strong is that we have had a tremendous input from foreigners or foreign-born people who come to this country for education and research and stay here, or those who were educated in other countries and come here and work.

We are all proud that something like half of the Nobel Prize winners since World War II are Americans. One-third of that half came from mostly European countries. So don't ever think that we don't owe a tremendous debt to them. We have got to continue to use that wonderful source.

Since this seems to be a year of priority-setting, we are going to have rough times, and the pressure is going to be on everyone. You can guess that I hope to be in there as an advocate of science and engineering education, as there will be advocates of everything else that is going to be impacted by Federal budget cuts.

I think we are going to have to make our case strongly, and I hope that in the priority-setting we get favorable treatment.

Let me tell you what I think are the priority fields for the National Science Foundation. We are still talking about science and engineering education. However, there is the other side of the National Science Foundation which supports the basic research in the universities in both science and engineering. I think that is the strongest input. The basic research support is the strongest single input that the National Science Foundation has had into the strength of our science and engineering education. That is my priority No. 1.

There is another priority that is growing more important every year. Over the last 3 years our engineering and science instructional equipment and our universities research equipment has been obsolescing. Some of it is already obsolete. We began almost a decade ago trying to push to get more support for such equipment. We didn't win in our priority battles. Maybe we did a little bit here and there.

Just this last year that has been recognized as a new initiative, but now the budget cut is threatening to wipe it out completely. We have to find a way to solve this problem, if we are going to stay strong in our science and engineering education. That is another high priority.

The National Science Foundation was sponsoring such programs as the Summer Institutes for Teachers which was fairly strongly supported by Congress, but not very strongly supported by administrations. Yet, there is the link between the research side of science and the universities, and the technology side and the industry. Those summer institutes, and other ways of upgrading high school teachers, are the link to secondary science education. I would like to see that kind of program continuing.

The fellowship support programs have been very effective, but in the years that I spent in the U.S. Government, I found that it was very difficult to convince administrators that science and engineering had any big call on public funds for their advanced education. I would like to see the fellowship programs continue, but I know that is tough sledding.

In curriculum development, some few of you veterans around know that we had difficulty in my time as Director of the National Science Foundation. I still think we have got to get some things straight before it becomes of really high priority. We have got to set up all of the mechanisms of government to encourage the industry to increase its support of science and engineering education.

Almost everybody agrees that we need this. We ought to be able to find solutions to this problem. Science and technology are terribly important to those segments of our powerful country that are currently threatened: Our economy, our national defense, and even our quality of life.

Mr. Chairman, thank you for the opportunity to testify to your subcommittee on the subject of science and engineering education. The importance of examining the growing number of problems in science and engineering education stems from the broadly accepted belief that a strong activity in science and technology is needed if we are to reach the goals that our leaders have set before us—to strengthen our economy and our national defense, and, at the same time, improve the quality of life for all. I don't know anyone who believes we can attain these goals on a long-term basis without employment of our fullest capabilities in science and technology.

[The prepared statement of Dr. Stever follows:]

My testimony today is based on the belief that we have indeed established a powerful program in science and technology in large measure because we have a fine science and engineering education system. We are not building from a weak base but a strong base, and that gives us encouragement to believe that we can solve some of the problems which have emerged in science and engineering education. There are, of course, many arguments as to what the specific problems are in our science and engineering education; there are even more arguments as to what can be done to attack those problems.

Among the perceived problems in science and engineering education are the following:

1. Recent studies by the National Science Foundation, the National Research Council and other organizations have indicated that there is not a serious long-term numbers problem with respect to qualified engineers and scientists. By the end of this decade, according to these studies, there should be an ample supply of educated men and women in these fields.

I am not sure that I agree with these conclusions, and I know that others do not. However, there does not seem to be an immediate crisis concerning the long-term supply of engineers and scientists.

There is broad agreement, however, that there are some immediate shortages in several fields of engineering and a few fields of science. As would be expected those who are in short supply are engineers and scientists for the burgeoning field of information sciences involving computers and communication, energy, and manufacturing technologies to strengthen industrial productivity.

2. Many engineers, and to some extent scientists, are leaving the educational ladder too soon, that is, at the bachelor's level, before they have reached their optimum educational potential. This apparently is due to the attraction of immediate high salaries in industry. Those staying for graduate degrees, especially the Ph.D. which qualifies them for professorial jobs in the universities, are too few to form a pool to replenish the ranks of university faculties.

3. It is evermore difficult to get qualified teachers of engineering and science at all levels, graduate, undergraduate, and secondary. For example, there is an estimated shortage of 2,000 in engineering school faculties right now. Reasons cited are: lower pay relative to industry and government; heavier teaching loads, with consequent reduction in research time; greater difficulty in finding the money to support research.

4. There is an excessive fraction of foreign students among the Ph. D. candidates, those from whom many of the future university teachers will be drawn. As a consequence, much of our basic research in the universities and much of our graduate student teaching assistance is performed by foreigners.

5. In most universities and colleges, there are serious shortages of needed instructional equipment, especially in engineering schools. Also, much equipment used in scientific and engineering research in universities is obsolescing or is already obsolete.

6. The secondary schools, on the average, are not maintaining a good supply of students in science and math courses; the quality of these courses on the average has dropped off; the supply of even marginally educated teachers for secondary schools is poor.

7. The match between some of the educational product, that is the graduates of the universities, and the needs of industry—now the largest employer of all these engineers and scientists—is not good. Perhaps this is more in the motivation to do basic research rather than work for the economically driven design and development problems of industry.

It should be noted that there is disagreement on this point. I have spoken to industrial leaders who say they are getting wonderfully well-educated students who can step right into their industrial jobs and do well. Others bemoan the mismatch. There are certainly differences in the attitudes depending upon which industry one is talking about. Some more mature industries, for example, employ practically no Ph.D.'s but prefer masters and bachelors; other industries, particularly those in computers and communications, are in great need of research scientists and engineers.

8. There is need for better understanding of science and technology, their methods, their results, their strengths and weaknesses, by men and women of all walks of life outside the fields of science and engineering; men and women whose lives will be heavily impacted by programs and change in science and technology, and who through political and social process can influence our overall science and technology progress.

In the following I will consider some proposed solutions to these problems:

1. It is somewhat gratifying that we do not face long-term shortages in the supply of qualified engineers and scientists, but only shortages in certain fields. This means that we do not need hastily conceived programs to mass produce engineers and scientists, programs that often leave long-term unsatisfactory situations. The true problems of today are those of addressing the specific immediate shortages of supply, and of improving quality throughout the system over the long term. We certainly must improve slippage from the good quality we have reached.

Many universities, often in cooperation with industries, are beginning to address the short-term needs. Effective communications are being established between industries and universities as to what these needs are. There are many ways of addressing the problem.

In the first place, industries can send to the universities some of their new bachelor degree hirees as well as some of their older engineers to take advanced courses in the areas of the shortages. Universities can set up cooperative programs for their students in industries with shortages.

Most important with respect to the short-term shortages, industry itself can do a great deal of teaching. Few people realize the extent to which our larger and stronger, high technology industries already have established superb in-house educational programs. There are many courses available to employees, and they have many highly qualified staff scientists and engineers to teach these courses.

I believe that the kinds of shortages we now see emerging can be handled on a reasonable basis by both universities and industries with techniques in cooperation that they have used in the past and are well equipped to use today.

Insuring the long-term quality of our science and engineering education is another matter. That is the most serious problem facing us, and it will require several different strong efforts.

2. It certainly is best in the long run to have the desired proportions of bachelor's, master's, and doctor's degree engineers and scientists emerging from our universities to satisfy the needs of industry and government, as well as of the universities themselves.

The apparent imbalance we have, caused by the young engineers and some scientists leaving at the bachelor's level, may not be solved quickly or easily. We must find ways around that.

The suggestions in the previous paragraph will help industry solve its short-term needs. The universities, however, have the continuing problems of qualifying Ph.D.'s for teaching careers, as well as improving both the pay and the research environment, so as to keep a fair share of the graduates at the universities.

3. This need to keep a proper flow of graduates through the Ph.D. degree into teaching in the universities is doubly important because we have chosen in this country to locate our basic research work at the universities. Both industry and government depend heavily on the universities for that basic research.

We must continue to find ways to get strong faculties for the universities, both for the teaching and the basic research roles. Most universities will tell you that more funding will solve this problem, allowing better faculty pay, improved teaching loads, allowing more time for research, and improved equipment and facilities.

4. There are many examples of great contributions to U.S. engineering and science by foreigners, both those who were educated in their own countries, and then came to this country to work, and those who came to this country for part or all of their education and then stayed to work here, many becoming U.S. citizens. I hope we still have the imagination and flexibility to use this source of strength to its fullest.

5. There is no question that most engineering schools are short of needed instructional equipment, and that research equipment in both science and engineering in universities in general is obsolescing. This must be addressed directly, by finding additional funds from those institutions which support the universities in their science and engineering research and education, that is, the Federal Government, the industries, and other private sources.

For a decade there has been a recognition by leaders in the engineering and science communities of this growing problem. They proposed initiatives to the Federal Government to strengthen both the research and instructional equipment in the universities, but the problem has never been given high enough priority to be solved by the government.

Now just as such an initiative has been accepted by the government, apparently the budget tightening will once again vitiate the effort. I think that is a mistake.

Industry can do its part, but I doubt it can do all of it. Most of our industries are, in fact, very anxious to set up cooperative programs, often built around specific short-term needs for engineers or special research results. The industries could solve the universities' needs for specialized research and instructional equipment by dealing directly with universities with which they are cooperating.

6. It apparently is true that the average level of attainment of the high school graduate in science and mathematics has been dropping. Students interested in careers in science and engineering seem to be doing well, for many college professors report that they are getting some of the best entering students ever. Clearly there are some secondary schools with highly motivated and qualified mathematics and science teachers. Still, the supply of good science and mathematics teachers in the high school is poor and apparently getting worse. It is clear that the voice of science and mathematics in many high schools is not a strong one.

I have always believed that the National Science Foundation's program called Summer Institutes for Teachers was a very good one. It gave the high school teachers instruction in the basic sciences and the emerging technologies. It gave them visibility and respect, and contributed to strengthening their voice in their schools.

Industry can also help in the high schools, though it is hard to see how this can be widely organized except through the professional engineering and science societies.

There are many cases where industries have made arrangements with local high schools so that members of the industrial engineering and science staff have assisted local high schools in their science, mathematics, and technology courses. This is not a highly organized effort except in the case of trying to improve the supply of minority engineers where industry developed a very strong, broadly spread organization called NACME, now the National Action Council on Minorities in Engineering.

If the interaction between industry and local high schools could be spread more broadly, for the purpose of strengthening all high school mathematics and science, the country would benefit.

7. The universities in the fifties, sixties, and early seventies, in what is referred to as the golden age of science in the universities, turned to the government for support and motivation in scientific research and education more than they did to industry. Industry lost some of its influence in the educational structure. That, fortunately, is changing at both ends.

The universities, probably in part motivated by the need for support and in part reacting to the criticism that they are not producing graduates to satisfy the needs of society, have tried to move toward satisfying industrial needs. Industry has clearly recognized its dependence on the colleges and universities and is trying to strengthen those bonds. I have great confidence that these movements will continue.

8. The frequently heard cries of members of our profession that we should promote broader public understanding of science and technology, is a tough one to deal with. We do know that Russian, Japanese, European schools seem to have a higher percentage than we do of all secondary school students getting some education in mathematics and science.

It certainly is one of their educational strengths to treat those subjects as basic in the primary and secondary schools, but I am not sure that it yields substantially better public understanding of science and technology. Personally, I am quite pleased with the progress the United States has made in public understanding of science and technology.

There are many superb publicly oriented television programs to upgrade audience understanding of the major science and technology issues of our time. All the other media do a good job on this. In the forty years of my active life in science and technology, the public understanding of science and technology and its implications, has steadily improved.

Science and engineering education is expensive. This is not because university tuition rates are increasing as a result of inflation. The expense of science and engineering education is a result, in part, of professors being highly paid for they are hired in a market that includes industrial jobs. Another reason for the expense is that the universities must provide an environment favorable to the research which professors conduct.

In this country our basic research is conducted at the universities; this is a great strength of our system, by the way, compared to other systems in the world. However, establishing the research environment and all that goes with it is expensive for the universities.

Following World War II, with the establishment of the National Science Foundation and some other units of government, the Federal Government clearly accepted the role of aiding science and engineering education, primarily by supporting research programs.

Government-sponsored research programs paid, in part, the professors' salaries as well as those of research assistant who were, at the same time, graduate students. Education was enlivened by the presence of those research programs on campus.

There has also been Federal Government support for science and engineering curriculum development, for scholarships, even for some facilities, buildings and the provision of specialized large-scale equipment.

In my view the most successful mode for equipment support of education has been through the direct support of research grants to professors. The methods of selecting high quality research to be done at the university through the peer review system has been remarkably successful. A great deal of today's U.S. university science and engineering strength is due to that direct Federal support.

If Federal support of science and technology must be tightened in order to reach other national goals, I believe that the direct research grant is the most important program to protect in that budget tightening.

The need for equipment for teaching and research is so great that a high priority, second only to that for research grants, must be given to it. Neglect of our equipment needs has been building for a decade at least, and we cannot maintain first-class science and engineering teaching unless we stop the neglect and begin now to reequip our laboratories and classrooms.

I want to stress again that the National Science Foundation-sponsored Summer Institutes for Teachers have been very effective, because they have not only upgraded the teaching of science, mathematics and technology, but they have also upgraded the importance of the mathematics and science teachers in the high school structure, and given them a more visible and powerful voice in the affairs of secondary education.

Fellowship support has also been very effective. From my own experience, however, I believe it very difficult to convince government officials that the fields of science and engineering are any more deserving of direct fellowship and scholarship support than any other fields. I would hope that the National Science Foundation fellowship programs continue. but I do know that they always will have uphill sledding because of this apparent equity problem.

The programs for a curriculum development, as far as I am concerned, have had mixed results. More thought must be given to objectives and methods before I will give them a high priority.

Industry should sharply increase its support in science and engineering education. Most of the industries I know are already moving to strengthen their university contacts; and this will be good from the standpoint both of the flow of information and understanding, and of additional financial support.

I think high-quality science and engineering education is vitally important for the long-term strength of this country as it strives to improve its economy, its national defense, and its quality of life and well-being.

~~I hope~~ that all of those concerned with science and engineering can continue to pinpoint accurately the activities where our tight funding can do the most. It will need the understanding and cooperation by the members of the university community, the members of the secondary and primary education communities, by members of industry, and by members of government in both the Administration and the Congress.

It seems that most of us agree that it is important to do a good job on this subject, and that it really is vital to our long-term strength. With that motivation, we ought to be able to get on with it.

Mr. **Walgren**. Thank you very much, Dr. Stever.

Mrs. **Heckler**. Doctor, I have enjoyed your testimony very much. I note that you have had a number of prior posts under two former Presidents.

Mr. **Stever**. Yes.

Mr. **Heckler**. You have heard Dr. Sagan comment about the lack of appointments in the scientific area.

Dr. **Stever**. Yes.

Mrs. **Heckler**. I wonder if you have been called upon to make any recommendations, or can you give me some advice which I might pass on to the administration? I am very distressed that there has not been more of a movement in terms of these appointments. Of course, I would like to see the appointment of some women scientists in key positions and in that program in general, but I wonder, do you have any insight to lend to the definite problem of personnel recruitment in the scientific field by the Reagan administration?

Dr. **Stever**. I was involved in the transition team in the period before the Christmas vacation, Then the transition became a transition essentially to the new Government, and I have not been involved on the inside, although I have had many calls with respect to people. They do have a good list of potential candidates for all of those science jobs. I know some people have been approached, and I believe there are others in the works.

I hope certainly that we get a science adviser soon because those posts are critical. There are dozens of them in the Federal Government. I know that the science community and lots of other people in the outside world are pretty anxious to see the President move to a science adviser appointment.

There always seems to be trouble, because people who are not in science think that the science adviser is an advocate of science, running around digging into the White House inner structure. He really should be of strong help to the President and his programs, and some science advisers have performed very well in that respect. We need one badly. We need a head of NASA, NOAA, and several other good appointments. You can go right down the list.

I hope that all of you will put any pressures that you have on them to go with the list they now have, and if they need help in getting further lists, there are dozens of us available to give them.

Mrs. **HECKLER**. Am I correct in my impression that some scientists have not been available? They have been recruited, and the offers have been rejected?

Dr. **STEVER**. Yes. It is a rough thing for a scientist to become a science adviser. There are a few of us who know this. You have chosen a public life. Science is a very attractive career, doing science instead of just interpreting science for society and handling its administration. That turns people away.

I think you know the salaries are a little on the rough side with respect to what they can get in other places, that is, total income if you take consulting, summer work, and lots of other things. Many of them are quite dedicated, and I am sure that you can get some. I know some who would serve right now if the right people asked them, but industrial scientists particularly find it difficult because they seem to have more of these conflicts that are hard for the public to swallow.

Mrs. **HECKLER**. It is obvious that there are many sacrifices that would be asked of the science adviser. At the same time this is a critical time to go in the right direction, a very exciting time. It is a very stimulating time, so this is a moment of very great challenge in the scientific field. I understand and shall pursue the issue with you again under a more suitable basis.

I am juggling priorities—we all are—dealing with the budget, dealing with restraint, limited resources, the tax pay revolt and also the needs of the scientific community, the need for education, development, et cetera. I, in my own mind, wonder how much of the load in terms of funding can be picked up by the private sector.

It seems quite clear your first priority is this basic research responsibility, probably because applied research would be funded by the private sector and basic research would not be considered sufficiently functional to be worth the kind of investment it takes. Is that right?

Dr. **STEVER**. It is not so much that it is not worth it; the worth appears in a longer time period, and the company doing the basic research is not necessarily going to be the one that capitalizes; by the time it is of value, it will be almost general property.

It isn't the worth value of it, but the company cannot capitalize on its own investments. It can on applied research and development, and so it approaches that.

You realize that there was a larger percentage of our basic research done in industry in an earlier time. In recent times inflation and other forces have forced all industries to a shorter term view of the future.

They cannot invest so far, and that, I think, has given the added burden to NSF, NASA, and other agencies of Government that have supported basic research. Yet, basic research is the thing that will really start a whole new industry, the computer industry, the solid state industry, and the genetic engineering industry.

Mrs. **Heckler**. You would say the basic research support is untouchable in the NSF budget; is that right?

Dr. **Stever**. Yes.

Mrs. **Heckler**. Is that the totally untouchable?

Dr. **Stever**. If NSF were to back off completely with education—I don't know whether it was Carl Sagan or Mike McCormack who said it earlier—that would be a signal that goes out to all of the school systems and the young people that something has happened and our Federal Government really isn't interested in that.

As soon as we can find other substitutes for that, that would be fine, but I think that there is needed visibility in the science education area.

I do think that there will be some priority choices needed, and I am glad that you are going to enter the period in which you are going to see lots of different people from the science and the engineering community who will give you their opinions.

I gave you my priorities in my testimony. They are listed here but there are others who may have different ideas about what our problems are. It is a very important process we are going through right now: whether the budget grows larger, stays the same, or becomes smaller, and I am putting in my advocacy right now.

Mrs. **Heckler**. Indeed, you have done so well.

Mr. **Walgren**. Thank you, Mrs. Heckler.

Mr. Brown?

Mr. **Brown**. Dr. Stever, I very much appreciate your statement and, as usual, it is very helpful to us in very practical decisions we have to make with regard to the funding of science.

If I may just interject a political note or two, or maybe I am trying to make it clear that what we are doing is not political. In this committee, there has been very little partisan debate on science issues. There has been a parochial debate in regard to the role of science in connection with other programs.

There will be in this committee probably some objections to cuts from the science budget this year, but there were equally objections to cuts in the science budget last year, and the administrations were very different, so we may be parochial but not partisan in our approach.

As a matter of fact, I am a little surprised and amazed to find that many of the people that I have worked with over the last 10 or 15 years here that I sometimes thought were Democrats, even turned out to be Republicans.

Dr. **Stever**. That even happens in the science community.

Mr. **Brown**. Right; so it is not a partisan thing that we are doing. The essence of my question is what is the value relationship of science programs to the range of other federally funded programs.

I am going to ask you to make a value judgment to help. Suppose we agree that it is necessary to cut the budget that we have before us, Carter budget, 10 percent, and that is about what the administration is trying to do, and that some of that will be cut 50 percent and some will be increased 50 percent; where would you put support for basic science programs on that spectrum?

Would they be in the middle and take their fair share of 10 percent?

Would they be somewhere down at the end of the 50 percent, or would you put them in the category of investment in the security, and you indicated that you felt science was related to our national security, our economic welfare, and our quality of life. On a scale of where you cut it in a budget, where would you put it?

Dr. **Stever**. Well, I am glad I was not elected to the Congress, facing that particular problem. Some of the things can be done by the private sector and can be done well. Some things can't be done so well. Some things can be shifted quickly and some things can't. I guess I would use those rules as I went through the various things.

I don't think that the support of scientific research in our universities, is going to be shifted quickly to the private sector. Some can be—and industry will step up to some of that—but I don't think it is wise to drop things until we have found a substitute.

I do think that there are lots of places where industry could do much better in the applied research and development.

The Government needs to establish the environment for industry to do it properly. Our society in the last 4, 6, 7 years has studied that question and has learned a lot about it. We ought to move on the things we have learned and make industry more effective in doing that job.

I guess I would pick basic research, and some elements of the science and engineering education program to make sure that they not fall between the cracks.

This is the seed corn for the future. As we are tackling our daily economic problems, we are not doing all that for the seed corn of the future.

Mr. **Brown**. You almost sound like you were back in the science advisory position and don't want to contradict the administration.

Mr. **Stever**. Let me say that I had admired Mr. Carter's approach, and his attempt to do better in human rights, but I also discovered that two of the most inhumane things that are going on in this country are inflation and unemployment, and by golly, if we don't lick those, we are not a very humane country.

Mr. **Brown**. Dr. Stever, let me point this a little more immediately, if I may.

I am not enamored with the idea of Federal support for science. I would just as soon it were carried on by universities and business, and they did before World War II largely.

There are some obstacles to that which you have pointed out. You can't capitalize on most basic research. That is an obstacle which Government has created. By removing the antitrust prohibitions against shared research by an industry sector, you could allow them to capitalize on it, and a whole sector of industry could share in the support of basic industry. Because that whole sector would benefit from it they could justify the Investment Act.

Suppose we change the antitrust laws and drop Federal support for basic education. Wouldn't that be a better way to go?

Dr. **Stever**. I go back to the Russian proverb, "Let's not throw away the old water until we get the new."

We can do a lot of good in changing the climate for industry for all kinds of research and its capitalization on research, and we have been trying to get those changes through in the form of tax changes, in the form of antitrust, and so on, and that was not simply a program of the last administration.

We tried it in the previous administration and did not succeed.

Maybe the voices of science and technology didn't work strongly enough then, but today I hope they are stronger.

You have a complex problem, and it isn't simply deciding how much NSF should get in order to strengthen science and technology in the country.

You have got several tools that you could use to strengthen it.

Mr. **Brown**. I think we recognize that in this committee, but we also recognize the difficulty of getting an integrated approach on the part of a fragmented Congress.

Mr. **Walgren**. Thank you, Mr. Brown.

Is there any way that you could describe where the training fellowships fit in in your ranking of priorities?

Dr. **Stever**. I think I had it fourth on my list of priorities.

Mr. **Walgren**. You said it was difficult to get support for that.

Dr. **Stever**. Yes; clearly even more so today.

They have done a great deal. By the way, the word "elite" every now and then pops up in the science and engineering fields, and I am an elitist in one sense.

I think we should very strongly give special treatment to some very unusual talents in our society, and that is what those National Science Foundation fellowships are aimed at.

I don't want any elitists who are given more rights and privileges and are hired at substantially higher pay or more privileges to walk over the other people in society. But I do think that those who have exceptional talents should be exceptionally treated, because the productivity of the very top ranked scientist or engineer is many times that of the average ones, and the productivity of the average ones is many times the ordinary.

You do want programs that really pull people out and move them rapidly, and that is what the National Science Foundation fellowships did.

It was a recognition of absolute top performance.

Mr. **Walgren**. How many fellowships were we carrying?

Dr. **Stever**. We had $50 million a year, as I recall.

Mr. **Gillespie**. I think it was more like 25.

Dr. **Stever**. It was 15 when I was there.

Mr. **Gillespie**. Right now it is not 25.

Dr. **Stever**. Five hundred new starts a year for all of the field of science and engineering. That isn't very many. That is really picking out a very small number.

Mr. **Walgren**. Well, we certainly appreciate your sharing those thoughts with us.

I want to recognize Mrs. Stever, who is in the audience. We are glad you both came.

If we have other questions from the members, perhaps we can submit them to you. Thank you very much.

Mr. **WALGREN**. The next witness is Dr. Donald W. McCurdy, who is president of the National Science Teachers Association.

Welcome to the committee. I am sorry we are going on so long today, but this is important ground that we are going over, and we appreciate your being with us.

Any written testimony you have will be printed in the record in full. You may summarize or proceed as you like.

[A biographical sketch of Dr. McCurdy is included in his prepared statement.]

STATEMENT OF DR. DONALD W. McCURDY, PRESIDENT, NATIONAL SCIENCE TEACHERS ASSOCIATION

Dr. **McCURDY**. Mr. Chairman and members of the subcommittee, I have written testimony which I will request become a part of the record.

I want to take this opportunity to summarize my written testimony and make some personal observations.

As part of my duties as president of the National Teachers Association, I spent the fall semester of this year traveling through 44 States, attending 17 State conventions of science teachers, visiting 100 schools and making contacts with hundreds of science teachers, and I have observed some very important and significant problems first-hand which I would like to relate to you.

One, I think that science has an image problem in the United States. I was in Harrisburg, Pa., for the Pennsylvania science teachers meeting, and that was a very vivid reminder of the Three Mile Island incident.

There has been a lot of recent press about chemical dumps and other forms of environmental degradation and other science-related issues.

I think there is a general feeling in this country that science has created some of our major problems.

The second problem that I have observed is a general attitude around the country that science is not a basic subject.

Legislation and debate about basics has left science out. I think this is vividly demonstrated by the recent decision by the National Assessment for Educational Progress to omit science from the next round of testing.

Related to this is the lack of science education at the elementary school level. As I traveled around the country I found very few exemplary elementary science education programs.

A recent NSF survey indicated that only 22 percent of elementary science teachers in this country feel confident to teach science. Obviously, that means four out of five don't feel confident and, therefore, tend to omit science from teaching.

Another problem is the lack of science, particularly physical science in the general education of students at the high school level. Approximately 16 percent of our high school students take physics. Approximately 35 percent take chemistry. Therefore, for the majority of students, the last physical science that they have taken is at the junior high level.

Two-thirds of all the States required only 1 year of science for graduation, and that generally turns out to be biology. Yet many of the problems that we face have their roots in the physical sciences.

Let me cite another personal example. At our institution we offer a noncredit physics course for people who come to the University of Nebraska deficient in physics. They have not had high school physics. Last year we had over 200 inquiries about this course. That is, there were 200 students graduating mostly from Nebraska high schools who had not taken physics but who were interested in becoming engineers.

Related to this problem is a critical shortage of qualified science teachers that is developing, especially in the physical sciences.

To cite another personal example, I was in Arizona this fall visiting a very nice school district, excellent facilities. They have about 200 applications for every teaching position they have in that school district. They had a physics position vacant this past year.

There were exactly two applications for that position, only one of whom was qualified.

The entire State of Connecticut last year prepared less than 20 science teachers at the secondary level. In two urban schools that I visited, they are paying a bonus to science teachers to keep them on.

These problems are not just my observations. They have been clearly documented in the report, Science and Engineering for the 1980's and Beyond—prepared by the National Science Foundation and the Department of Education, as well as a number of other studies.

This report states, "There has been over the past 15 years or so a shrinking of our national commitment to excellence and international primacy in science, mathematics and technology."

Now, I recognize that the Federal Government cannot solve all of those problems alone, but I think that with limited funds the science education directorate and other branches of the Federal Government have done a remarkable amount of work toward meeting the needs of science education.

As I look around this room and see all the NASA photographs, I am reminded of a program that we are running for NASA which provides an opportunity for young people to design experiments to go aboard the Shuttle on a space-available basis.

Philosophically, I am in wholehearted agreement with the President's goal to balance the budget, but I believe that this must be accomplished fairly and equitably, based on sound criteria of what is in the national interest.

The association that I represent is deeply concerned about the proposed OMB budget cuts for NSF. They would essentially eliminate one of the two major functions of this agency.

I recognize that these cuts outlined on the last page of my written testimony have not been officially announced, but they are common knowledge around the Washington area, and I believe they were even reported yesterday in the New York Times.

We believe that if those cuts are allowed to get through the Congress, that it will have a dramatic effect on the quality of science education in the long run. A strong basic research program funded by NSF is absolutely essential, but a viable research program is based on a sound and healthy elementary, secondary, and undergraduate program.

We cannot starve the fundamental basic science and mathematics education at the lower levels and expect the research to thrive at the top. It is important to note that the proposed OMB cuts for science education do not follow the President's original guidelines for budget cuts. The original guidelines call for an overall increase of 6 percent for all NSF programs.

I would like to call your attention to the graph on page 6 of my written testimony which clearly demonstrates the decline in NSF support for science education.

This, I think you will note, roughly parallels the decline in science test scores as documented in the National Assessment Reports and in other sources.

Last night I was privileged to attend the awards banquet in honor of the 40 high school student winners of the Westinghouse science talent search. This was a vivid reminder that the most valuable resource we have is our bright young people. Unfortunately, they do not have many lobbyists or spokesmen to testify on their behalf.

I have to argue a little bit with Dr. Sagan when he says that science education in this country is abysmal. I visited a lot of schools all over the country and I found some excellent programs, and I think those students that were honored last night are evidence of that fact, but I implore you to remember those productive young people when you consider the budget for science, mathematics, and engineering education.

Also, I want to say that we don't expect the Federal Government to do it all. Let me assure you that the National Science Teachers Association and other professional associations will be working aggressively to solve the problems of science education in this country.

If I had time, I would enumerate some of our efforts in this regard.

I thank you for this opportunity to present my concerns.

[The prepared statement of Dr. McCurdy follows:]

TESTIMONY

TO

THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

OF

THE COMMITTEE ON SCIENCE AND TECHNOLOGY

OF

THE U.S. HOUSE OF REPRESENTATIVES

IN REGARD TO

1982 AUTHORIZATION FOR THE
SCIENCE EDUCATION PROGRAMS
OF THE NATIONAL SCIENCE FOUNDATION

PRESENTED BY

DONALD W. McCURDY
PRESIDENT
NATIONAL SCIENCE TEACHERS ASSOCIATION

DATE: MARCH 3, 1981

The following testimony is submitted to the Subcommittee on Science, Research, and Technology of the Committee on Science and Technology of the U.S. House of Representatives. The author of this testimony is Donald W. McCurdy, President of the National Science Teachers Association (NSTA). The NSTA is the largest science education organization in the world. It is concerned with the professional aspects of science education at all levels and for all science disciplines.

Dr. McCurdy is a science educator who has taught chemistry and physics at the college and secondary levels and is currently professor of science education at the University of Nebraska-Lincoln. His education, taken at the University of Missouri, U.C.L.A. and New Mexico Highlands University includes graduate degrees in science and education, so that he has a broad perspective of issues in science and education.

TEXT

The President's efforts to reduce inflation, if made in the even-handed and fair way he has proposed, deserve the full support of all Americans. There are indications, however, that budget cuts are being proposed which, in some instances, have been decided upon at lower levels of OMB for political, not for economic reasons. The size and complexity of the federal budget are such that these distortions of Presidential intent are not easily apparent, and since such programs are often small, they are not given much time or attention at top administrative levels. The Science Education component of the National Science Foundation is an example of such a program.

OMB Distortion of NSF Mission

The mission of the National Science Foundation has, since its inception, been to strengthen the scientific research and science and engineering education capabilities of this nation.

> "The Foundation is authorized and directed (1) to initiate and support basic scientific research and programs to strengthen scientific research potential and science education programs at all levels..." (NSF Act of 1950).

Since 1967, when the science education component of NSF accounted for about one-third of the entire NSF budget, the science education share has been systematically reduced to its present low level of 7.5%. If the OMB proposal for 1981 is accepted, science education will suffer a further loss of 20% in 1981, lowering its share of the total NSF budget to 6.4%.

In the OMB budget proposal of February 18, 1981, the1982 science education budget had been reduced from the $112 million proposed by former President Carter to $65 million, a reduction of 42%. In the budget proposal to be made on March 10, 1981, the OMB will start the process to totally eliminate programs of the science education component of NSF, thereby changing the mission of this agency from its dual purposes of strengthening scientific research and science education to just research. About $10 million will be left, and it will be used only to meet commitments already made for Graduate Fellowships.

Lack of Adherence to Budget Reduction Criteria

In setting priorities for budget decisions, the President imposed certain criteria. The NSF was specifically mentioned in Criterion #6:

> "Fiscal restraint must be imposed on programs that are in the national interest but are lower in priority than the national defense and safety net programs. Examples include...National Science Foundation... which would be allowed to grow at lower rates than planned."

Contrary to this criterion, the budget proposed by OMB would increase support for research in the "hard" sciences by 14%, while drastically reducing and eventually eliminating the essential science education component of NSF. The 14% increase for "hard" science research also violates the President's stated policy that "...Federal spending growth must be held to 6% in FY 82..."

Lack of Consideration of Alternatives

In the president's speech to the nation, he directed a question to those of us who might be unwilling to accept OMB's budget plans: "Have they an alternative?" But OMB did not provide an opportunity for alternatives, even within agencies where cuts had to be made. In the case of NSF, where the President's criteria did not even call for cuts, and instead allowed growth at a slower rate, no alternative proposals were sought nor considered. Neither the Director of NSF, the National Science Board, nor the Science Education Advisory Committee were given an opportunity to prepare alternative proposals which would meet the budget requirements. Had these experts been asked to do so, they would have made the cuts, while maintaining proper balance of program support among areas of high national priority. The budget decisions were made entirely at OMB by staff with narrowly limited research expertise and strong biases against NSF support of its science education component. These staff had neither access to appropriate information and input, nor accountability for solving the national crises we face in science and engineering education.

The National Crisis in Science and Engineering Education

The national crisis in science and engineering education exists and has been well-documented in numerous surveys and studies. The most recent national examination is presented in a joint, National Science Foundation-Department of Education publication, Science and Engineering Education for the 1980's and Beyond (NSF 80-78, October, 1980). Since this publication appeared, numerous other studies have shown that the problems it identified have further intensified.

The shortage of qualified mathematics and science teachers in secondary schools has reached crisis proportions. Population changes and population mobility over the next ten years will make these shortages even more acute in some parts of the country. Engineering faculty at the post-secondary level cannot be found, and this problem will increase in severity. The science content at the secondary level is mismatched to the practial needs of most students, and appropriate alternatives do not exist. Schools and colleges have not been able to keep up with the revolution in modern technology, so that laboratories are hopelessly obsolesent. The erosion of teacher support systems and resources for science and mathematics teaching have led to reductions in the achievement of students in these fields at the very time when such knowledge is essential to work and live in our technological society. The essential role of computers in all aspects of our society is being restrained largely by the severe inadequancies of computer education. Where computers and microprocessors have revolutionized modern industry and business in more productive countries, our educational system has not prepared personnel with the skills and knowledge needed to utilize these innovations.

The President's programs to bring the nation to higher levels of productivity through advanced manufacturing and industrial technology and to improve our defense preparedness through the same advanced technology, are doomed to complete failure if we do not provide the people who must do these jobs with the essential scientific and technological education and training.

A 1982 Science Education Component for NSF

The documented failures and deficiencies in American science education can be attributed in part to the erosion of funding support for science education at NSF over the past 15 years. While research funding has been increased enormously over this period, science education has been reduced to an almost negligible proportion of the total NSF budget. We now see the unpleasant results of this shortsightedness and negligence. Given the level of support available, the science education directorate has done extraordinarily well in attacking many of the very serious national problems in science education. They have made gains in research on how people learn science, on bringing computers and telecommunications into schools and colleges, in the development of some new practical science curricula, and in providing science to children and the public through innovative broadcast TV programs. Through the Science Education Resources Improvement programs, NSF has helped many schools and colleges keep current with materials, equipment, and curricula. The Science Personnel Improvement programs have maintained an adequate flow of scientists through graduate fellowships. By means of the NSF Chautauqua-Type Short Courses program for college teachers and the Pre-college Teacher Development program, the NSF Science Education directorate has helped substantial numbers of science teachers improve their competencies in what are probably the two most cost-effective government programs in existence. The Science Education Directorate has used its funds remarkably well, but there simply has not been enough to do the job that was needed.

If the national mandate to reduce federal expenditures is to be met, the science education component of NSF, like the research components, must focus only on problems of high national priority.

In Science Education this can best be done by emphasizing the following areas:

- Upgrading the scientific, mathematical, and technological competencies of teachers at the pre-college level;
- Providing graduate fellowships in computer science, engineering, and applied math and science fields where there are critical shortages of personnel;
- Development of applications-oriented and practical science and mathematics instructional materials for schools and for lower divisions of colleges and universities;
- Bringing a larger proportion of women, minorities, and handicapped into science and mathematics;
- Helping colleges and universities upgrade laboratory apparatus, including especially microcomputers, microprocessor-based equipment, and other apparatus which form the components of high-technology industry;

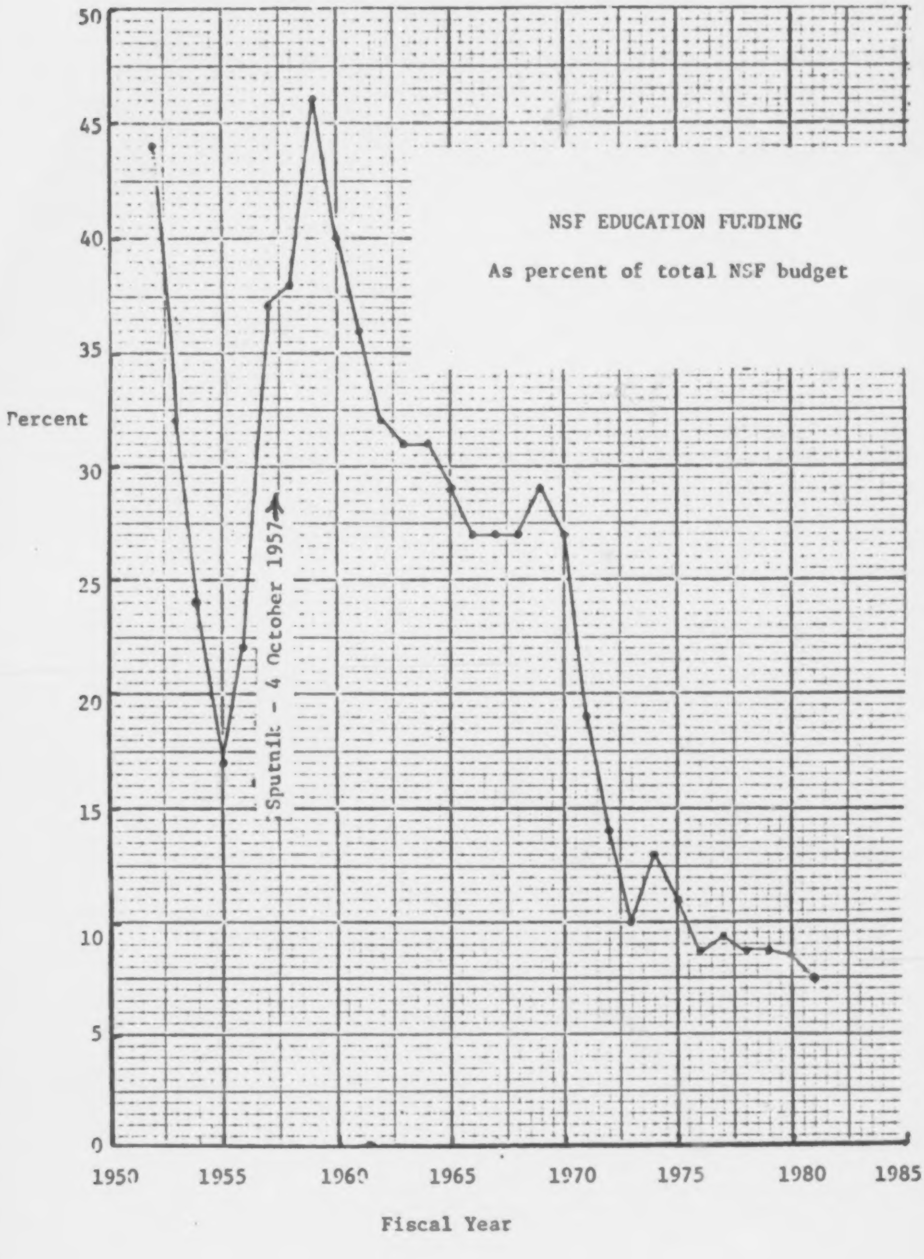
- Development of instructional materials to inject the use of computers into essentially all science and math courses, as appropriate, at all levels;
- Provide high quality, targeted science programming by TV for children and adults to help reduce the widening gap between what is known about science by working scientists and what is known by those who are not scientists, but who must work and live in a technological world;
- Continue the process of research on how people learn science and mathematics.

In addition to these areas of emphasis, the NSF science education directorate should continue to provide some graduate fellowships in science and mathematics, and the directorate should continue other of its important programs in Science Education Resources Improvement, Science Education Development, and Science Personnel Improvement, but at a reduced level.

Recommended Program Authorization for NSF Science Education for 1982

An NSF Science Education authorization is recommended which would emphasize the areas of highest priority, while allowing the science education budget to increase only by the 6 percent growth limit required by the President for NSF programs.

NSF SCIENCE AND ENGINEERING EDUCATION PROGRAMS	1982 Recommended Authorization (in millions)	
Science Education Development and Research		
Science Education Development		
Applications-oriented materials for secondary schools	4	
Applications-oriented materials for lower divisions of colleges and universities	3	
Computer-oriented materials	3	
	10	
Science Education Research		
Research on Learning Science and Engineering	2	
Research on Learning Mathematics	2	
	4	
Total		14
Science Personnel Improvement		
Pre-college teacher development	18	
College teacher development	5	
Graduate fellowships in computer science, engineering, applied science, and math	13	
Women, minorities, and handicapped in science	3	
	39	
Total		39
Science Education Resources Improvement		
Computer equipment for science, math and engineering instruction	10	
Apparatus for science and engineering instructional laboratories	8	
Pre-college science and math resource centers	5	
College science and math resource centers	2	
	25	
Total		25
Public Science Education Improvement		
Children's science through TV	4	
Radio, Museums, and magazines science program	2	
	6	
Total		6
Special projects in science, math and engineering education	2	
Total		2
		86


NSF EDUCATION FUNDING
As percent of total NSF budget
Percent
50
45
40
35
30
25
20
15
10
5
0
1950
1955
1960
1965
1970
1975
1980
1985
Fiscal Year
Sputnik - 4 October 1957

NSF SCIENCE EDUCATION BUDGET COMPARISONS

(Amounts in millions of dollars)

PROGRAM	Present 1981 Budget	Reagan 1981 Budget (After $16 Million cut)	1982 Reagan Budget 2/19/81	1982 Reagan Budget 3/10/81
Science Personnel Improvement				
Graduate Fellowships	11.4	11.4	15.0	9.9*
Minority Trainee Fellowships	3.2	3.2	-	-
Post-Doctoral Fellowships	-	-	-	-
Engineering & Computer Traineeships	-	-	3.0	-
	14.6	14.6	18.0	9.9*
Undergraduate Research Participation	3.0	3.0	-	-
Student Science Training Program	2.7	2.7	-	-
	5.7	5.7	-	-
Pre-College Teacher Development	7.2	7.2	12.0	-
Industrial Research Participation	0.8	0.8	1.2	-
Faculty Conferences Program	-	-	2.8	-
Science Faculty Professional Development	2.2	2.2	2.0	-
Science Faculty Short Courses	-	-	2.0	-
	10.2	10.2	20.0	-
Minorities in Science	1.0	1.0	1.0	-
Women in Science	2.5	2.0	2.0	-
Science for Physically Handicapped	0.5	-	-	-
	4.0	3.0	3.0	-
Science Education Resources Improvement				
Comprehensive Assistance to Undergraduate Science Education	13.0	8.0	-	-
Instructional Scientific Equipment	3.2	3.2	15.0	-
Local Course Improvement	2.8	2.8	-	-
Resource Centers for Science & Engineering	2.8	2.8	-	-
	21.8	16.8	15.0	-
Science Education Development & Research				
Science Education Development	9.0	4.1	3.0	-
Research in Science Education	6.1	4.0	2.0	-
	15.1	8.1	5.0	-
Science Education Communications				
Public Understanding of Science	4.3	2.6	3.9	-
Ethical Values in Science & Technology	2.0	2.0	-	-
Science for Citizens	1.7	1.7	-	-
Information Dissemination in Science	1.3	-	-	-
	9.3	6.3	3.9	-
TOTALS	80.7	64.7	64.9	9.9*

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*This $9.9 million is to phase out graduate fellowships.

Mr. **Walgren**. We appreciate that very much, Mr. McCurdy.

Mr. Brown, do you have any questions?

Mr. **Brown**. No. I want to get it straight here. You have a table attached to the last page of your statement?

Dr. **McCurdy**. Yes, sir.

Mr. **Brown**. It is from the best information available?

Dr. **McCurdy**. Yes, sir.

Mr. **Brown**. The plan apparently in the Reagan budget is to cut from the $80 million that was originally proposed all but $9.9 million. Is that the gist of what your charts convey, sir?

Dr. **McCurdy**. That is the information that we have; yes, sir.

Mr. **Brown**. Do you think that that can be done without a revision in the Organic Act of the National Science Foundation which stipulates that the purpose of the Foundation will be the support of education and science and engineering?

Dr. **McCurdy**. I am not a lawyer. I certainly am not qualified to answer that question, but in my opinion it would seem to me that there would need to be a change.

Mr. **Brown**. The figures that you have listed in the second column 1981, represent a $16 million cut below the budget that was presented by the Carter administration. In your opinion, could the science education community live with a cut of that substance amounting to about between 15 and 20 percent?

I think that is the kind of a decision that this committee will make. Whether accepting that large a cut would still give us a program that would meet the minimum requirements for science and education.

Dr. **McCurdy**. In my opinion, of course, I don't really think we can afford any cuts but, if there are cuts, I really sincerely believe they ought to be equitable and I don't think that science education should be cut any more than the research budget.

Mr. **Brown**. Well, thank you very much. I think this puts the options before us in a fairly stark perspective, and we very much appreciate your contribution.

Dr. **McCurdy**. The figure I have in the original Carter budget was $112 million.

Mr. **Brown**. Oh, yes.

Mr. **Walgren**. Thank you very much, Dr. McCurdy. We appreciate your contribution.

The last group of witnesses will be a panel of Dr. Daniel Drucker, dean of the College of Engineering, University of Illinois; Dr. Samuel Hulbert, president of Rose Hulman Institute of Technology; and Dr. Lionel Baldwin, dean of the College of Engineering, Colorado State University.

We appreciate your patience this afternoon and say that any written submissions you would like to make will be made part of the record.

Dr. Drucker?

[A biographical sketch of Dr. Drucker follows:]

Dr. Daniel C. Drucker

Daniel C. Drucker is Dean of the College of Engineering at the University of Illinois, Urbana-Champaign campus. Dr. Drucker received a B.S. degree in 1937, a C.E. degree in 1938, and the Ph.D. in 1940, all from Columbia University. Prior to becoming Dean at Illinois in 1968, he was associated with Cornell University, the

Armour Research Foundation, U.S. Army Air Corps, Illinois Tech, and was at Brown University for 21 years where he served as Chairman of the Division of Engineering and as Chairman of the Physical Sciences Council.

Dr. Drucker has authored one book, over 130 technical papers, and a number of articles on Engineering and Society. From 1956 to 1968, he was Technical Editor of the Journal of Applied Mechanics (ASME).

Dr. Drucker is president-elect of ASEE. He is a member of the National Academy of Engineering and the American Academy of Arts and Sciences. He is President of the International Union of Theoretical and Applied Mechanics, a member of the General Committee of the International Council of Scientific Unions, a past president of the American Society of Mechanical Engineers, the Society for Experimental Stress Analysis, and the American Academy of Mechanics.

He has been awarded the von Karman Medal of ASCE, the Lamme Medal of ASEE, the M. M. Frocht Award of SESA, and the Egleston Medal of the Columbia University Engineering Alumni Association. In 1976 he received an Honorary Doctor of Engineering degree from Lehigh University, and in 1980 was made a foreign member of the Polish Academy of Sciences.

He is a registered professional engineer in Illinois and Rhode Island.

STATEMENT OF DR. DANIEL C. DRUCKER, DEAN, COLLEGE OF ENGINEERING, UNIVERSITY OF ILLINOIS

Dr. DRUCKER. Thank you, Mr. Chairman.

I am glad the material we submitted will be part of the written record.

Time is running very short, and I thought I might depart considerably from what I have written in view of the testimony you have heard so far.

It is very clear, and I think all of us on this panel would agree, that there is a need for support for all of the activities that Dr. Sagan spoke about, that Congressman McCormack spoke about that Dr. Stever and also Don McCurdy have spoken about.

The three of us are here to convey to you the alarming but real picture of the crisis in engineering education.

Let me try to describe it, if I may. I should report that the problem that is being faced by the schools and colleges of engineering is the multibillion dollar problem that you described in your opening remarks. A problem which somehow disappeared from view in the testimony presented earlier today.

Mention has been made of the projections in the report to the President which stated explicitly that by 1990 most of the science and engineering manpower shortages would disappear.

That, of course, is true in a rough and meaningless sense. If you add up all the social scientists and all the physical scientists and all the engineers there will be enough people. I would caution you also that the people who made the projection that at the Ph. D. level there will only be occasional shortages in a few fields of engineering are the same people who 10 years ago predicted large surpluses of engineering Ph. D.'s today. Yet within the universities alone we are short of 2,000 engineering faculty members for the budgets we have. I should make it clear, that when I say we or engineering, I include computer science.

Engineering and computer science are unique. There is no other sizable field in which there is a shortage of available faculty. Physics is part of the college of engineering at the University of Illinois at Urbana-Champaign, and part of my general jurisdiction.

We are short of money, but when we have money, good physicists are available and can be obtained. Chemistry is not part of my jurisdiction. When they have money, good chemists can be obtained.

It is not true for chemical engineering, not true for any of the engineering disciplines. The main point is that a bad situation is going to get progressively worse and worse.

The reason it is going to get progressively worse and worse has to do, of course, with the very high and increasing industrial demand. It is true that if the universities offered twice the salaries they offer now, they would get more people, but then industry would be short. Industry is already short at the Ph. D. level. There simply are not enough people in the pipeline, not enough people coming out.

In my written testimony I talk about the national need, first, as one should, the need for a high level of engineering performance. A high level of engineering performance requires two things: Enough well educated people—with bachelor, masters, and doctorate degrees—and a rich knowledge base.

The point which often is missed, perhaps by some of the people from whom you have heard testimony today, is that when you have a change in the input, the effect is felt strongly only after some years go by. Because of this time lag, we have descended over the past 5 years into an ever-deepening crisis in engineering education.

There are those 2,000 unfilled faculty positions at the present time but, even worse, an appreciable percentage of the engineering faculty at many schools are people without appropriate high qualifications.

As you know, industrial salaries for beginning engineers at each of the levels—bachelors, masters, and doctorate—zoom up a tremendous amount year by year.

Admission pressure is enormous from high school graduates of the highest quality ever. Despite the difficulties at the primary and secondary school levels, with the other people who are not entering engineering or science, those students we get are better prepared than ever before.

But each year, more and more schools are limiting engineering enrollments, and the engineering education system is very close to a point of instability. Our Nation faces a crucial decision.

If we cannot increase our staff appreciably then we must cut enrollments significantly. Otherwise, educational quality will simply be unacceptable. If we cut enrollments, then our industrial and our defense enterprises will be unable to function effectively in a few years. The word "crisis" is not an exaggeration.

What are the contributors to the crisis? I mentioned a number, but let me add that only half as many of our upper decile undergraduates now go on to the Ph. D. as did 10 years ago or more.

We have a 2,000 shortage of engineering faculty and fewer than 1,400 domestic students go on to the Ph. D. in engineering each year. About an equal number of Ph. D.'s in engineering are awarded to students coming to us from other countries.

It may be a cause for concern but should come as no surprise that year by year there is an increase in a fraction of the engineering professorate who receive their undergraduate education in their home country overseas and that at very many engineering schools today, the great majority of all new appointees are not U.S. citizens.

I share Dr. Stever's great admiration for the contributions of the people from abroad. Our industrial establishment would come to a halt were it not for these Ph. D.'s who came to us from other countries. However, the quality of those Ph. D.'s is not increasing.

It is in fact decreasing, for good reason. Educational opportunities are improving in many countries. Their students stay on at home to get their Ph. D.'s.

So we feel that we must persuade about 1,500 additional students a year from the upper 10 percent of our roughly 60,000 a year bachelor engineering degree graduates to go on to complete a Ph. D.

Unless that is done, the situation will progressively deteriorate.

I think we all agree that a severe national problem requires national attention, but without any more Federal Government intervention than is appropriate and necessary.

Universities themselves, industries, State governments, private giving, all must do as much as possible.

The Federal Government has an important role to play as a catalyst, but more than that, in parallel with industry, the Federal Government in the areas of defense and in the mission agencies is a large employer of engineers, and therefore, if industry should do something, so also should the Federal Government.

Let me turn to the role of NSF.

Again, let me keep emphasizing that one should not lump science and engineering together.

The problems of science are real and important and must be paid attention to. But they are different, entirely different than the problems of engineering, except in a few overlap areas. We believe the time has come for NSF to assume its mandated responsibility for the continuing advancement of the health of the engineering disciplines in the same measure and with the same degree of devotion that it now has for the disciplines of basic science.

A substantial start on the solution to the crisis lies squarely within the present mandate of NSF. Here we would give first priority to the traineeship-fellowship program for engineers and computer scientists.

Without it, we will not get those additional people desperately needed by industry, universities, by the country as a whole. Next comes the instructional equipment program to begin to replace over $1 billion of obsolete equipment, and then the typical NSF research role, an expanded program of fundamental engineering research addressed to the manmade world of today and tomorrow.

I should point out that the total research support for engineering at the universities, academic engineering, in this country from all agencies of the Federal Government is only one-third of the total NSF budget.

NSF has proposed to move in each of the three key areas. Though this initiative is late, it is to be applauded, strongly encouraged, and further enhanced. At this time, with a new distinguished director who bridges engineering and science, a simple name change to the National Engineering and Science Foundation would provide reassurance for the future and help avoid an undesirable schism between engineering and science.

The cost of those three essential programs is far from trivial and only a small portion should be borne by the Federal Government, but the cost of doing nothing is catastrophic and the payback in economic health and in national security resulting from addressing the issue resolutely will be very high.

The total proposed for the fiscal 1982 year amounts to a significant addition to the present NSF support for engineering, but a small enough fraction of the total NSF budget to make it a worthwhile and appropriate investment for the Nation.

Time is indeed running out. A clarion call for action and this minimum amount of seed money is needed soon to provide the needed leverage and so preserve the stability of the engineering educational system in this country.

Failure to act in time will set this country irretrievably on the painful path of becoming a second rate world power in the economic and military spheres.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Drucker follows:]

Statement of

DANIEL C. DRUCKER

Dean College of Engineering

University of Illinois at Urbana-Champaign

My name is Daniel C. Drucker. I am Dean of the College of Engineering of the University of Illinois at Urbana-Champaign, a past-president of the American Society of Mechanical Engineers and president-elect of the American Society for Engineering Education. I appreciate greatly this opportunity to appear before you and explore with you the dimensions of the crisis in engineering education, its impending terribly adverse impact on the industrial and defense capability of the nation and the future well-being of our people.

The Deans of Engineering of all the Schools and Colleges of Engineering meet together at least twice a year. Many subgroups, among them the Deans of the Big 10 Schools plus Berkeley, MIT, and Stanford also have been meeting regularly for some years. Therefore the analysis presented is a genuine group consensus in its broad outlines. The proposed beginnings of a solution also have near universal agreement. However, when I get to detailed numbers and dollar amounts I should caution you that my suggestions for an appropriate response by the Federal government are viewed by many of my colleagues as far too conservative, perhaps totally inadequate in the face of what is a multi-billion dollar problem.

With the caveat, with your permission, I shall outline the contents of the document before you entitled THE CRISIS IN ENGINEERING EDUCATION.

THE CRISIS IN ENGINEERING EDUCATION

Daniel C. Drucker

Summary

A qualitative and quantitative picture begins with the present unmet national need for an adequate number of well-educated engineers at the B.S., M.S., and Ph.D. levels by industry and the mission agencies of government, including defense, despite a somewhat low level of economic activity and defense spending. Root causes of the ever-deepening crisis in engineering education are outlined. The major point made is that the severe and increasing shortage of engineering faculty, facilities, and instructional equipment in the face of the enormous and still growing attraction of engineering to the best and greatest number of undergraduates ever in our history is bringing our engineering education system closer and closer to a point of instability.

A traditionally appropriate, relatively small seed money response from the federal government through NSF is proposed to begin to exert effective leverage on what is a multi-billion dollar problem as well as a people problem. The universities themselves, industries, mission agencies, state governments, and private giving must make the major contributions.

Attention is called to the inevitable and irretrievable catastrophic effects on our industrial and defense capability unless something substantive is done very soon.

The National Need

A high level of performance of the engineering profession is essential for our continued industrial vitality and for our national defense. So also is it basic to the ability of our local, state, and federal governments to provide needed public services. The quality of life and the economic well-being of the people of our country depend on many factors but they cannot be maintained, much less improved, without an ever increasing U.S. engineering competence.

The continued vitality and effectiveness of the engineering profession, in turn, is directly dependent on two inputs. One is an adequate number of well-educated engineering graduates at the B.S., M.S., and Ph.D. levels. The other is the knowledge base of the many engineering disciplines, sub-disciplines, and cross-disciplines. Changes in these inputs, whether for better or worse, are felt strongly by industry, government, the military and the nation as a whole only after several years have elapsed.

The Crisis

Perhaps because of this time lag we have descended, over the past 5 years, into an ever-deepening crisis in engineering education, a crisis that has just begun to become clearly visible to our industrial community. At meeting after meeting held this past year, academic participants have reported on the sad situation in engineering (including computer science) at their respective universities, whether large or small, public or private, world-renowned or more locally significant. A consistent and alarming picture has emerged of the severe problem soon to be faced by our highly technological society because of the growing crisis in our schools and colleges of engineering. The continually increasing shortage of engineering faculty at each of the schools was described in some detail and provided both confirmation and understanding of the reported figure of about 10% nationwide or 2000 unfilled positions at the present time. The news of this shortage of present and available faculty, has been all but buried in the avalanche of reports of great surplus in almost all other disciplines with their long waiting lists of disappointed applicants. Each school labelled the present 10% shortage of engineering professors not just as uncomfortable but as severe or acute and viewed the situation as one of crisis. The problem is far deeper and more pervasive than just a 10% shortfall in presently budgeted positions.

In comparison with 10 or 12 years ago, the 10% fewer professorial people than budgeted are teaching over 30% more students for a more than 40%, not a 10%, overload or decrease in attention per student. Furthermore, an appreciable percentage of the faculty at many schools are holdover retirees or temporary people without a doctorate or equivalent high qualifications. The most active and effective members of the faculty are overworked, overtired, and rapidly becoming dispirited.

The high and rapidly increasing starting salaries offered to our graduates provide clear evidence that the industrial demand for engineers substantially exceeds the number of graduates at each degree level, B.S., M.S., and Ph.D. B.S. graduates this year are likely to average $23,000 with many at $25,000. Our nation has a critical unmet need for an adequate number of properly educated engineers to maintain and improve our economic well-being and to provide for our national security.

Our nation faces a crucial decision. Each year we see an increasing number of the brightest students eager to be admitted to the study of engineering at the undergraduate level. Admission pressure is enormous from high school students of the highest quality ever. Yet, each year more schools are limiting engineering enrollments. The faculty is torn between their desire to accommodate the present number of undergraduates and their recognition that the present excessively high student to faculty ratio degrades the education experience they can offer. Lack of essential modern instructional equipment, support staff, and suitable facilities greatly aggravates the situation.

The shortage of engineering faculty will become ever more acute over the next few years and will become catastrophic in less than a decade unless substantial corrective measures can be taken. The engineering education system is very close to a point of instability. If staff cannot be increased appreciably, enrollments soon must be cut significantly if educational quality is to remain acceptable. If enrollments are cut appreciably our industrial and defense enterprise will be unable to function effectively in a few years. The word "crisis" is no exaggeration.

Contributors to the Crisis

There are several major contributors to the problem. One is that university salary scales are low on average and move only slowly to provide the differentials required by outside competition.

Therefore the disparity between academic and industrial salaries for engineers has become so large and the academic life so much less attractive that professors are leaving for industrial positions in ever greater numbers while the reverse flow is drying up. Engineering Ph.D.s are no longer choosing the academic life in the approximately 1 out of 3 pattern of the 1960s. Furthermore the total number of Ph.D.s turned out each year has dropped appreciably, while the fraction of them who are suitable for both teaching and research at the university level is at a low point. A drastically decreasing fraction and consequently a much smaller total number of our best undergraduates have opted for graduate study in the past decade. Only half as many of our upper decile undergraduates now go on to the Ph.D. as did 10 years and more ago. Fewer than 1500 of all of our undergraduates now obtain a Ph.D. each year. An almost equal number of Ph.D.s in engineering are awarded to students who come to us from other countries.

Even with an adequate academic salary scale for engineers to restore the earlier 1 out of 3 choice, less than 300 of the total of 2700 domestic and foreign Ph.D.s a year would be eligible and available to teach on the reasonable assumptions that industrial demand will remain high and that quality instruction of undergraduates requires selection from among the upper third (or higher) of all Ph.D.s. In the research universities the selectivity must be greater still because professors on average also must be far superior in ability to their Ph.D. students on average. It may be a cause for concern but it should come as no surprise that year by year there is an increase in the fraction of the engineering professoriate who received their undergraduate education in their home country overseas and that at very many engineering schools the great majority of new appointees are not U.S. citizens.

The Dimensions of the Increasing Shortage of Faculty and the Minimum Added Supply Needed

There are now more than 20,000 professors of engineering. Therefore the attrition due to retirement, and the necessary weeding out process of selection before the granting of tenure, would require about 1,000 entrants per year to the academic engineering community in the steady state. The less then 300 eligible and available with our present 2,700 output per year clearly projects a substantial increase in the shortage of adequately qualified faculty each year unless the supply of superior engineering Ph.D.s is increased substantially and some of the attractiveness of academic life is restored. It is unrealistic to expect industry to refrain from competing for our best students and consequently unrealistic to expect more than half of our best Ph.D. students to embark on an academic career. Industry too requires its share of the brightest and the best. If graduate student fellowships, traineeships or stipends were raised to their traditional fraction of starting salaries for B.S. engineers, that should persuade 1,500 additional students a year from the upper 10% of our 60,000/yr B.S. engineering graduates to go on to complete a Ph.D. If half of them then started as assistant professors the shortage would cease to grow in about 5 years.

A Start on a Solution - The Role of the Federal Government

A severe national problem requires national attention with no more federal government intervention than is appropriate and necessary. The universities themselves, industries, state governments, and private giving all must do as much as possible, much more than they have done in the past 5 years. Nevertheless the federal government also has an important role to play as a catalyst when it is in the national interest to do so. The allocation of relatively small amounts of seed money can serve as leverage by calling attention to the problem and the need for massive support by other sectors. However, the federal government has a far greater role still in the amelioration of the crisis in engineering education. In parallel with industry the federal government in defense and in the mission agencies is a large employer of engineers at all levels. The defense establishment, today, needs engineers and advanced engineering concepts on a large scale. To an appreciable extent the crisis in engineering education is specifically a problem for the federal government as well as for the entire nation.

The Role of NSF and Others

The time has come for NSF to assume its responsibility for the continual advancement of the health of the engineering disciplines in the same measure and with the same degree of devotion that it now has for the disciplines of basic science. A substantial start, both psychological and substantive, on the solution to the crisis in the schools and colleges of engineering lies squarely within the present mandate of NSF. The three key areas in which NSF leadership would effectively exert great leverage on the other sectors that must contribute far more funding are traditional ones for NSF. They are:

a traineeship-fellowship program for engineers and computer scientists to dramatize the demand and the opportunity and so attract the needed 1,500 or more each year of our brightest undergraduates to continue on to the Ph.D.

an instructional equipment program to begin the needed moderization of undergraduate and first-year graduate engineering laboratories, to begin to replace over a billion dollars of obsolete equipment,

an expanded program of fundamental engineering research to help educate a greater number of Ph.D. engineers while developing the knowledge base for the man-made world of today and tomorrow.

A side remark is appropriate here. The total research support of the entire academic engineering enterprise in this country from all agencies of the federal government is only equal to 1/3 of the total NSF budget. The present inadequacy of NSF's support of engineering in the universities has become a cause célèbre. Resolutions adopted by the major engineering societies attest to the growing feeling among engineers that a National Engineering Foundation is needed in parallel with NSF to help provide the nation with the fundamental knowledge base required for subsequent industrial innovation and enhanced productivity. However, NSF now has proposed to move effectively in each of the three key areas. Although this initiative is late it is to be loudly applauded, strongly encouraged, and further enhanced. At this time, with a new distinguished director who bridges engineering and science, a simple name change to the National Engineering and Science Foundation would provide reassurance for the future and help avoid an undesirable schism between engineering and science.

The cost of each of these three essential programs is far from trivial and only a portion should be borne by the federal government. However the cost of doing nothing is catastrophic and the payback in economic health and in national security resulting from addressing the issue resolutely will be very high. The entire minimum need traineeship-fellowship program in its first year requires $10,000/yr × 1,500 or $15,000,000 and in its third year and beyond about $40,000,000/yr to the students and an equal cost of education allowance to the departments or schools in which the students study. The more than billion dollar deficiency in equipment has already been mentioned. A $500,000,000 expansion in research per year is about the proper number on the conservative side once the additional graduate students are in the pipeline. The well over a billion dollar salary deficiency and the multi-billion facility and building deficiency add to a total far beyond NSF's scope and mission and well beyond the federal government's responsibility.

It would seem appropriate now for NSF to fund half of the student stipend fellowship-traineeship program or $7,500,000 in the first year, $14,000,000 in the second and $20,000,000 in the third year and beyond. Mission agencies would find it in their interest to fund the remaining additional students. Industry would be called upon to increase the support for the present number of students to counteract their pull of $23,000/yr starting salaries this year. Universities will need an equal amount from all of their sources of support to cover their additional costs.

A modest contribution through NSF of $25,000,000/yr for engineering instructional equipment would signal the need to continually replace a billion dollar inventory. So also would an additional $50,000,000 in research funding in FY82, and equal increments for each of two successive years, highlight the much greater need which must be met by mission agencies, by much more extensive university-industry cooperative endeavors, and by state governments.

Concluding Remark

The sum total proposed here for the FY82 year amounts to $82,500,000 for NSF, a significant addition to the present NSF support for engineering but a small enough fraction of the total NSF budget to make it a worthwhile and appropriate investment for the nation. Time is running out. A clarion call for action and this minimum amount of seed money is needed soon to provide needed leverage and so preserve the stability of the engineering educational system in this country. Failure to act in time will set this country irretrievably on the painful path to becoming a second-rate world power in the economic and military spheres.

Mr. **Walgren**. Thank you very much, Dr. Drucker.

Dr. Hulbert.

[A biographical sketch of D. Hulbert follows:]

Dr. Samuel F. Hulbert

1976–present: President, Rose-Hulman Institute of Technology, Terre Haute, Indiana.

1973–1976: Dean of Engineering, Tulane University, New Orleans, Louisiana.

1970–1973: Associate Dean for Engineering Research and Interdisciplinary Studies, Clemson University, Clemson, South Carolina.

1968–1971: Head of the Interdisciplinary Studies, Clemson University, Clemson, South Carolina.

1964-1968: Faculty member, Clemson University, Clemson, South Carolina.

1964: Ph. D.—Ceramic Science, Alfred University, Alfred, New York.

STATEMENT OF DR. SAMUEL HULBERT, PRESIDENT, ROSE-HULMAN INSTITUTE OF TECHNOLOGY, TERRE HAUTE, INDIANA

Dr. **Hulbert**. Mr. Chairman, because of the lateness of the hour, I am only going to address what I consider to be the most critical problem, and that has to do with the severe shortage of engineering faculty members. I am persuaded that the intelligent use of new technologies will provide the answer to many, if not most, of this country's problems. I am convinced that for it to happen now, there has to be an adequate supply of appropriately trained and educated engineers. In this country at the present time there is a severe shortage of engineering faculty. There are approximately 20,000 engineering faculty in this country, and there are about 2,000 to 2,500 budgeted vacancies. This is the not the total story, though, because that same number of faculty are teaching more students than they were 10 years ago, so there is in the shortfall a 40 percent shortage of available faculty for student interaction. The problem is going to get much worse.

We are graduating approximately 2,700 Ph. D. engineers in this country at the present time, and of this number approximately 1,400 are American citizens. Of this number about 25 percent are interested in exploring academic careers. This means that maybe there are 400 each year. Retirements are about 600 a year. Attrition and the weeding out process calls in the neighborhood for something over 1,000 faculty each year. Only 400 are becoming available for the university shortages now of at least 2,000 or 2,500. You can easily see what is going to happen in the short term.

I would like to speak for just a minute about what we are doing collectively in engineering education to solve these problems. Some of the things we are doing is we are asking people who would normally retire to stay on. We are hiring part-time people. We are hiring people without Ph. D.'s. None of these is necessarily bad, but I believe it is also not in the best national interest. We have larger class sizes. We are cutting down on the number of laboratories. We are retaining people that we would normally let go because we can't replace them, and we are allowing nonengineers, people without an engineering background, to teach a larger and larger portion of the engineering curriculum, and all of this will spell eventually a decrease in the quality of the education engineers are receiving in this country.

I believe of all of the priorities being considered here today, the top priority ought to be given for the establishment of 2,000 fellowships, assistantships, or traineeships for graduate engineering and computer science students. Thank you.

Mr. WALGREN. Thank you very much, Dr. Hulbert.

[The prepared statement of Dr. Hulbert follows:]

Statement of Samuel Hulbert, President
Rose-Hulman Institute of Technology

DR. HULBERT: Mr. Chairman, because of the lateness of the hour I am only going to address what I consider to be the most critical problem in the area of science and technology facing our country, and that has to do with the severe shortage of engineering faculty members. I am persuaded that the intelligent use of new technologies will provide the answer to many, if not most, of this country's problems. I am convinced that for it to happen now, there has to be an adequate supply of appropriately trained and educated engineers. In this country at the present time there is a severe shortage of engineering faculty. There are approximately 20,000 engineering faculty in this country, and there are between 2,000 and 2,500 budgeted vacancies. This is not the total story, though, because that same number of faculty are teaching more students than they were 10 years ago, so there is in the shortfall a 40 percent shortage of available faculty for student interaction. The problem is going to get much worse.

We are graduating approximately 2,700 Ph.D. engineers in this country at the present time, and of this number approximately 1400 are American citizens. Of this number about 25 percent are interested in exploring academic careers. This means that there are approximately 400 eligible and available new engineering faculty members this year. Retirements are projected to be about 600 a year for the next ten years. Attrition and the weeding-out process calls for in the neighborhood of something over 1,000 new engineering faculty each year. With only 400 becoming available, the present engineering faculty shortage of at least 2,000 positions is going to grow dramatically during the next decade.

I would like to speak for just a minute about what we are doing collectively in engineering education to solve these problems. Some of the things we are doing is asking people who would normally retire to stay on. We are hiring part-time people. We are hiring people without Ph.D.s. None of these are necessarily bad, but I believe we are also doing other things that are in the long run not in the best national interest. We are increasing class sizes. We are cutting down on the number of laboratories. We are retaining people who we would normally let go because we can't replace them, and we are allowing non-engineers, people without an engineering background, to teach a larger and larger portion of the engineering curriculum, and all of this will lead soon to a decrease in the quality of the education our engineering graduates are receiving in this country.

I believe of all of the priorities being considered here today, the top priority ought to be given for the establishment of 2,000 fellowships, assistantships, or traineeships for graduate engineering and computer science students. Thank you.

STATEMENT OF DR. SAMUEL F. HULBERT, PRESIDENT, ROSE-HULMAN INSTITUTE OF TECHNOLOGY

SEVERE ENGINEERING FACULTY SHORTAGE: A NATIONAL CRISIS

INTRODUCTION

Twenty-six representatives from the engineering education and industrial communities met at Shakertown at Pleasant Hill, Kentucky on December 3-4, 1980 for the purpose of discussing the growing crisis facing our nation as the result of the severe shortage in engineering faculty members. It was hoped that the collective wisdom of the assembled group could develop strategies to begin to alleviate the crisis.

At the opening session each representative from the academe gave a review of the problem from the perspective of his campus. Then each industrial representative presented his estimate of future needs for engineers, particularly those with graduate training. The next portion of the program was devoted to a discussion of possible solutions to the problem. Each participant was asked to propose three steps which could be taken to begin to solve the problem. On the morning of the second day, three concurrent workshops were conducted. One looked at the role of the federal and state governments in developing solutions to the problem; the second addressed the role of industry; and the third covered the role of colleges and universities. At the conclusion of the workshops, a report was given to the whole assembly.

Following is a summary of the discussion which took place at the Shakertown Conference and consensus recommendations and conclusions which evolved from the conference:

STATEMENT OF THE PROBLEM

A combination of circumstances has brought our schools and colleges of engineering to a crisis state that will continue to worsen unless strong and immediate measures are taken. There is presently a severe shortage of engineering faculty. There are approximately 20,000 professors of engineering in the United States. There are between 2,000 and 2,500 budgeted faculty vacancies in engineering schools at the present time. The shortage will continue to worsen. We are graduating approximately 2,700 engineering Ph.D.'s in this country per year; however, only about 1,400 of these are American citizens and only about 25% of this number are going into academia. The attrition due to retirement and the necessary weeding-out process of selection to find appropriate engineering teachers require about 1,000 entrants per year to the academic engineering community in the steady state. The less than 400 eligible and available new faculty members clearly project a substantial increase in the shortage of faculty year by year unless the supply of engineering Ph.D.'s is increased substantially and the attractiveness of academic life is restored.

The problem is far deeper and more pervasive than just a 10% short-fall in presently budgeted positions. In comparison with ten or twelve years ago, the 10% fewer engineering faculty than budgeted are teaching about 30% more students for a 40%, not a 10%, overload or decrease in attention per student. Furthermore, an appreciable percentage of the faculty at many schools are hold-over retirees or temporary people without a doctorate or equivalent industrial experience. The most active and effective members of engineering schools faculty are overworked, underpaid and rapidly become dispirited.

Admission pressure is enormous from students of the highest quality ever. The industrial demand for engineers substantially exceeds the number of graduates at each degree level, B.S., M.S., and Ph.D. Our nation has a critical unmet need for an adequate number of properly educated engineers to maintain and improve our economic well-being and to provide for our national security. Each year we see an increasing number of the brightest students eager to be admitted to the study of engineering at the undergraduate level. Each year more schools are limiting engineering enrollments. The faculty is torn between their desire to accommodate the present number of undergraduates and their recognition that the present excessively high student to faculty ratio degrades the education experience they can offer. Lack of essential modern instructional equipment, support staff, and suitable facilities greatly aggravate the situation. Engineering education requires extensive laboratory equipment and facilities. It is a requirement which has been sorely neglected for the past two decades and the result is serious obsolescence of present equipment and facilities. In most cases potential faculty members can find far better facilities for continuing their scholarly activities at industrial laboratories than at a university setting.

The shortage of engineering faculty will become ever more acute over the next few years and will become catastrophic in a decade unless substantial corrective measures can be taken. The engineering education system is very close to a point of instability. If staff cannot be increased appreciably, enrollments soon must be cut significantly if educational quality is to remain acceptable. A major contributor to the problem is that the disparity between academic and industrial salaries for engineers has become so large and the academic life so much less attractive that professors are leaving for industrial positions in ever greater numbers while the reverse flow is drying up. Engineering Ph.D,'s are no longer choosing the academic life in the approximately 1 out of 3 pattern of the 1960's. Furthermore the total number of Ph.D.'s turned out each year has dropped appreciably, while the fraction of them who are suitable for both teaching and research at the university level is at a low point. A decreasing fraction and much smaller total number of our best undergraduates have opted for graduate study in the past decade.

A high level of performance of the engineering profession is essential for our continued industrial vitality, the ability of our local state and federal governments to provide many essential public services, and the economic well-being and the quality of life of the people of our country.

It is a national disgrace that our present undergraduate engineering students, the best of the past three decades at least, and likely the best ever, are being deprived of a proper engineering education. Their loss is more than an individual loss; it is a critical loss to the nation. If an appreciable fraction of the best students went on to graduate school, some of the inadequacies would be corrected. Partly because starting salaries in industry for B.S. engineering graduates have at least kept up with inflation and so appear very high, partly because fellowship and graduate assistant stipends have fallen far behind, and partly because of the flood of misleading information discouraging graduate study in general, fewer, rather than more, of our best engineering students continue their studies. The negative result of the total irretrievable loss of effective technical manpower will be devastating to future industrial innovation and productivity if permitted to continue much longer.

There are two parts to the problem:

a. An on-going shortage of high quality American Ph.D. graduate students of engineering, and

b. Deficiencies in the job content, pay, and facilities required to attract faculty in engineering schools.

SOLUTIONS TO THE PROBLEM

Four general categories of causes for the shortage of engineering faculty are perceived, each suggesting its own type of solution. There is little question that all four categories play an important role, and that therefore no single solution can be expected to be effective in isolation.

The four categories are:

1. The lack of public understanding and appreciation of technology
2. The frequent lack of motivation for embarking on engineering teaching careers
3. The necessity of strengthening direct methods for increasing graduate students, number of faculty, and teaching productivity

4. The necessity of strengthening various means of industry/university cooperation

The first category refers to a long-standing problem, not amenable to quick and ready solutions. Nevertheless there is little question that a campaign aimed at increasing public awareness and understanding of the benefits which technology, properly applied, can bring, would be of great value. In particular, it is essential that public officials be fully aware of the still increasing role which technology plays in our lives and in the nation's welfare and security. No less than a national technology policy is called for to meet the seriousness of the problem.

The motivation of students and others to enter the engineering teaching profession can be greatly strengthened by active encouragement by present faculty. Increasing opportunities for part-time industrial employment would, no doubt, be attractive to many prospective engineering teachers.

The most effective immediate solution to the problem lies, of course in the several direct means of action. Prominent among these is the re-establishment of NSF support for engineering graduate students, whether it be through fellowships, assistantships or traineeships, with or without forgivable provisions for teachers. Other sources of support, particularly at the state level, should prove fruitful as well.

Sources of excellent engineering teachers, other than the traditional one of new graduate students, should be tapped by universities and colleges with more flexibility than has often been the case in the past. Examples are the possibilities of greater use of retirees from both industry and academe, of foreign-trained people, of graduate students, of industrial personnel on sabbaticals or on release time, of M.S. holders while continuing their studies toward the Ph.D. Certainly improved conditions in the universities would play an important role in attracting qualified individuals; this refers to such matters as lower teaching loads for young faculty and better equipment for teaching and research, but also, and more importantly so, to get salaries in the academe more closely competitive with those in industry.

A fundamental cause of both the shortage of faculty members in critical areas and the severe impact of inflation on the cost of higher education is the fact that higher education is a labor-intensive industry. Most earlier efforts to increase productivity have resulted in lowering of quality. This is true both of the growing size of lectures and of certain attempts to utilize television, computers, and other technologies in teaching. However, in the long range, this situation must and will change. Particularly in engineering, we will find ways to use technology to assist our educational tasks. If done well, it will individualize and thus personalize learning rather than depersonalize it. However, some of the technology is not yet available and the cost of that which exists, is extremely high. But, as the faculty shortage becomes increasingly critical, it is hoped that the incentive to develop and utilize appropriate technology will cause significant changes to occur. Realistically, this will not result in lessening the need for faculty during the next five years. However, if efforts start soon, significant relief might be expected to occur soon thereafter.

Industry and academia must collaborate to an ever increasing degree if a solution to the shortage of engineering teachers is to be approached. Industry must recognize that enlightened self-interest dictates that it seek means to implement such collaboration, while at the same time universities must be receptive to new industrial approaches. Various methods have been explored, and more must be tried with greater vigor: examples are teaching sabbaticals for industrial people, adjunct professorships on release time, university/industry co-hiring, and joint research projects.

Essential to the desired collaboration is the establishment of a favorable tax climate for its survival and growth.

CONCLUSIONS AND RECOMMENDATIONS

The following is a summary of the conclusions and recommendations of the Shakertown Conference:

1. It should be recognized that the shortage is a national problem and not one that can be laid solely on the doorstep of engineering education.
2. We believe that a position paper or white paper clearly describing the problem is necessary in dealing with representatives of the federal and state governments. We recommend that the AAES and/or the National Academy of Engineering prepare such a document as soon as possible and make it available to those who will be dealing with the problem.
3. We recommend that legislation be passed in the 97th Congress which would increase graduate engineering fellowship support and provide for more equipment grants for engineering instruction and research laboratories.
4. There now exists a government/industry relationship in each state which is working to bring new jobs to the state and to hold current jobs. Engineering educators should attempt to establish a link with this group in state government, or with the industrial people who are now dealing with state government and federal government on these matters.
5. The federal and state governments should provide incentives, either direct subsidies or tax incentives which would

encourage people to move from industry to the university on a temporary basis. The loan of industry engineers as part-time faculty members would not only ameliorate the current shortage of faculty but help translate current practices into the classroom.

6. The Conference Board and/or the Chamber of Commerce should be induced to gain the support of industry and to work directly with those in engineering education and industry who are dealing with this problem. We believe that a strong clear position taken by the Conference Board would have substantial impact on industry and the federal government.
7. We believe that a national technology policy is required and that engineering education must be an important component of the policy.

The preceding discussion of causes and solutions emphasizes the fact that the depth of the problem requires a multi-faceted attack for its solution. The critical nature of the problem cannot be over emphasized, and the dangers in leaving it unchecked must be remembered; nevertheless it is equally important to bear in mind that, perhaps in distinction to some of the other pressing national issues, this one is, however difficult, still amenable to a solution if attacked with foresight, vigor and determination.

Mr. **Walgren**. Dr. Baldwin.

[A biographical sketch of Dr. Baldwin follows:]

Dr. Lionel V. Baldwin

Lionel V. Baldwin has served as professor and dean of the College of Engineering at Colorado State University, Fort Collins, since 1964. He is chairman-elect of the Engineering College Council of the American Society for Engineering Education which consists of over 240 deans of engineering. Baldwin is immediate past-chairman of the Board of the Association for Media-based Continuing Education for Engineering—AMCEE is a consortium of 22 major engineering colleges which use modern telecommunications to serve the educational needs of engineers at their job sites.

Baldwin received his academic degrees in chemical engineering from the University of Notre Dame (B.S., 1954), M.I.T. (S.M., 1955) and Case Institute of Technology (Ph. D., 1959).

AMCEE Member Universities are listed below:

Auburn University
Case Western Reserve University
Colorado State University
Georgia Institute of Technology
Illinois Institute of Technology
Massachusetts Institute of Technology
North Carolina State University
Polytechnic Institute of New York
Purdue University
Southern Methodist University
Stanford University
University of Arizona
University of California, Davis
University of Idaho
University of Illinois at Urbana-Champaign
University of Kentucky
University of Maryland
University of Massachusetts
University of Michigan
University of Minnesota
University of South Carolina
University of Southern California

STATEMENT OF LIONEL BALDWIN, DEAN, COLLEGE OF ENGINEERING, COLORADO STATE UNIVERSITY, FORT COLLINS, COLO.

Dr. **Baldwin**. Thank you very much, Mr. Chairman. I have submitted a statement which is rather lengthy. I would like to have it put in the record.

Let me simply echo the sentiments of my colleagues in engineering education that the critical shortage is in fact a faculty shortage, the human resource.

Engineering graduates have to play a very important role in our Nation's reindustrialization drive. It is a fact that most of the capital investments that are proposed to increase U.S. productivity will be designed by engineers. Our ability to produce more engineers in the coming decade is going to be very severely limited by the inability of our engineering schools, which are near saturation now, to accommodate more students. We have many excellent students at the door, but we are having to turn many away. So we won't have significant increases of engineering graduates in the coming decade to help with this reindustrialization drive.

It is almost too late to intervene in the faculty shortage area. I urge, however, that we get started in our faculty rebuilding program so that 5 years from now we will not find ourselves in a worse condition, because of the projections and logical conclusions of the numbers we have just heard.

Another area in which we can make an investment is to improve the productivity of the engineers we do graduate. This committee has had a long interest in the role of educational technology and information technology in education broadly. One of the reasons I may have been invited to speak to you is that later this month the

National Academy of Engineering will publish a report that K. S. Down, associate dean of engineering at Stanford, and I wrote concerning how computer graphics videotechnologies and telecommunications can play an increasing role in the practice of engineering in the marketplace, and in the education of our engineers while on campus. It is a very important leverage which we have in this country if we choose to make the capital investment. The opportunities for better designs, the opportunities for examining more alternatives in greater depth, the opportunities for better control, the opportunities for increased reliability—the tools to do these tasks are rapidly becoming affordable and distributed throughout industry. But our schools are lacking the modern equipment. Therefore, as we look to engineering graduates to carry our technology into the marketplace, we find that the colleagues are very ill-equipped to supply a modern education program.

I know that you are searching for what role the Science Education Directorate and education in general plays within the scope of NSF activities. Out of my statement, I would like to cite one example that is close to home.

In this country the engineering schools over the last 12 years have developed very close regional links with neighboring industries. We have been supplying graduate courses directly from our classrooms to off-campus engineers. As we teach on-campus students, we also deliver these courses to industry by a whole variety of telecommunication means: public television, high frequency broadcasting, videotape. We have found that we were adding to our classroom practicing young engineers who are doing advanced design work in the neighboring industry. But these television-based programs are essentially regional operations paid for by the industry that is involved, even though there is an appreciable capital investment, at least on the order of several hundred thousand dollars, if not more, on the part of each university. This is a very healthy system, a very appreciated system, but it has some definite limitations.

In 1976, although there were 30 universities reaching over 20,000 engineers annually with graduate courses offered by television, we found that over half of the engineering population in the country was totally unserved. There were not enough regional systems. Furthermore, if you looked at who was taking the courses, you found they were essentially the young engineers under 30 years old, new to the job. Yet the average age in most plants of the engineering population was closer to 45 years old. So there was a large population even within plants served that was not being reached by regular graduate courses. They had a direct need for more direct application oriented courses—continuing education courses, short courses.

This is the kind of role, the kind of initiative, the kind of opportunity that the National Science Foundation Science Education Directorate can capitalize on. NSF Science Education enabled a consortium of 22 universities to come together. It gave the group startup funds in a phased fashion to make regional programs into national programs.

One university dared not undertake it, given the problems we have in meeting the on-campus demand. Furthermore, in the regional programs the off-campus engineers were essentially using the curriculum paid for by the on-campus students, and piggybacking on it. All we had to do was to deliver that because it was a graduate course already designed. If we were to reach the older engineers, it was essential that new curriculum be developed, aimed specifically at them. No regional system could support these original startup costs. We had to have a marketing co-op, a consortium of universities.

Furthermore, we had to be in business to be self-supporting. You had to convince industry first that you could deliver. They would be very happy to pay for the service, but you had to prove that you had a service to offer. Hence, the NSF science education directorate grant to the Association for Media-based Continuing Education for Engineers (AMCEE) has enabled us after 4 years to offer some 450 courses in some 26 different engineering disciplines to 22,000 additional engineers at their job sites, more than doubling the initial enrollment when you include both graduate education and continuing education. Once AMCEE was operational, we found we could find support from private foundations. But you need the right initiative at the right time, and I think this is the unique role that the National Science Foundation plays: A seed role, a very important, critical, and high leverage role that NSF science education plays in demonstrating the use of educational technology, not only in engineering education but throughout the educational system. Because I realize I am preaching to the choir, I think I will stop.

[The prepared statement of Mr. Baldwin follows:]

STATEMENT

On March 16, 1981, the National Academy of Engineering will issue a report entitled, "Educational Technology in Engineering", which I coauthored with K. S. Down, Associate Dean of Engineering, Stanford University. The principal results of the study are the basis of this statement.

Importance of Engineering Talent

Engineers play an important role in our nation's reindustrialization drive. Most capital investments to increase productivity are designed by engineers. Furthermore, we look to young graduates to help introduce the latest technologies.

The 1970's were a trying decade for the United States. Out of the past ten years, two alarming, interrelated trends have been identified. The first trend is the decline in industrial productivity. The second trend is a leveling or even a slight percentage decline in the number of engineers entering the technological sector. Both of these trends are counter to the majority of the industrial world. For example, major European industrial nations have increased productivity over the 1970's while Japan has actually doubled the percentage output of engineers over the last 10 years. These developments have serious implications for the economic well-being of the United States and the life-style of its citizens.

Peter F. Drucker, management consultant and professor, recently reported on a series of interviews with Japanese businessmen. In the November 3, 1980 issue of Fortune, he wrote:

> Again and again, my Japanese friends pointed out what they consider to be the basic difference in the way Japan and the U.S. discern opportunities: "You in the United States have in the last ten years doubled the number of people in law schools, while you barely even maintained the number of people in engineering schools. We in Japan have not increased the number of lawyers but have doubled the number of engineering students. Lawyers are concerned with dividing the pie, engineers with making it larger."

Importance of Educational Technology

Since it does not appear that significant increases in U.S. engineering enrollments will occur during this decade, alternative action is required. The engineering graduate of the 1980's must be capable of increased design analysis and evaluating power, greater manipulative capability and tighter configuration control than our engineers have obtained during the previous decade. One obvious solution to this problem is to enhance the engineer's productivity through increased usage of the computer via analysis, modeling and graphical presentations and manipulations. The engineering graduate must be capable of bringing increased productive skills to play if the United States is to continue its leadership role within the technological society.

The study focuses on the increasing role of interactive computing, computer graphics, videotechnologies and telecommunications in the practice of engineering and in the university education of engineering students. These technologies are resulting in improved quality of design and productivity, and, therefore, offer important opportunities to our nation.

Highlights from the Study

Educational Technology (ET) encompasses not only the use of materials and hardware to aid in the learning process, but also the systematic organization and presentation of knowledge to the learner. The rejuvenated interest in ET today stems from the microelectronics revolution of the past decade which, coupled with digital and laser system development, is just starting to produce useful instructional hardware that is more powerful and more affordable. Indeed, some items are intended for direct consumer purchase.

The greatest impact of instructional television (ITV) in engineering has been in linking universities with industrial and governmental facilities. In the past decade, over 30 engineering colleges have developed regional ITV systems which today serve about 20,000 engineers at their job sites with regular graduate classes from the campus. These programs are popular, effective, and continue to proliferate. No federal funds are involved. A wide variety of delivery systems are successfully employed including the ITFS (Instructional Television Fixed Service) and standard public broadcast bands, point-to-point microwave and videotape.

But much of the nation did not have this service in 1976. Furthermore, noncredit continuing education service was lacking. The National Science Foundation Directorate of Science Education played a critical role at this point. NSF supplied a phased grant to enable a cooperative consortium of 22 of these colleges to develop a national delivery program which includes both graduate and continuing education for engineers and technical managers. This year, the Association for Mediabased Continuing

Education for Engineers (AMCEE) is offering over 450 courses in 26 disciplines to over 22,000 engineers, which brings the total served to over 42,000 people at their job site. AMCEE, once underway with NSF help, has also attracted start up funds from the Alfred P. Sloan Foundation and today is well on its way to a self-sufficient operation paid by services rendered.

In the initial demonstration of many educational technologies, there is an important role for NSF to play.

Satellites offer a unique opportunity to develop both nationwide programs and resource sharing with foreign educators. The engineering profession brings a background of tried and tested educational services to the "new" communications technologies. Experiments have already shown that use of a satellite could overcome three current operational problems: technical--ITV signal can travel only a short distance at a reasonable cost; logistical--the mail and other delivery services are slow; and financial--videotape inventory is expensive. In addition, unique features such as teleconferencing could assist in the co-management of education tasks both between U.S. industries and universities and, if it were deemed appropriate, between foreign universities and U.S. universities. The domestic application has been studied in detail by AMCEE; satellite delivery of ITV could be break-even in 2 to 4 years from initiation if capital were available for the ground facilities.

The recent advent of personal computers and inexpensive videodisc systems coupled with microprocessors is stimulating renewed interest in computer assisted instruction (CAI). University presidents may welcome the consumer "takeover" of computing which during the 1976-77 academic year consumed $991 million, about three quarters from university funds and the remainder largely from federal agencies. Less than 50 engineering colleges recently reported some use of CAI, but virtually all (238) reported use of computers for problem solving activities.

Very few educators have the experience necessary to make effective use of the new CAI hardware immediately. The first task is, therefore, to enlarge the group of engineering and physical science faculty who study and test the medium's potential in small working groups at many universities. Like all technology, ET requires key human resources for implementation. The appropriate adoption of ET is seriously hindered by the historical lack of a broad scale, sustained effort to enlarge the number of talented individuals working with media. Private industry has recently attempted to sponsor some work along these lines.

The greatest payoff of the new hardware in engineering education will be through interactive computing combined with graphics. These facilities can provide unique learning experiences that will develop skills in synthesizing and analyzing, as well as assist in visualizing, thus creating intuitive skills. Applications of computer-aided design and computer-aided manufacturing need to be introduced in virtually all engineering colleges which today lack the instructional facilities to serve students properly. This is a pressing, massive problem; it needs to be addressed squarely. NSF, the federal mission agencies, industry, private foundations and state governments will all be called upon to play a role.

The rapid introduction of measuring instruments that incorporate microprocessors and digital memory is widening the gap between industrial practice and university laboratories. The emergence of these powerful new instruments and control devices is outpacing the equipment budgets of universities. Traditional laboratory procedures are being changed fundamentally by the built-in data analysis programs of the instrumentation. Unlike most of the ET discussed herein where courseware is the dominant issue, the instrument revolution described above is essentially a hardware problem.

Suggested Actions

Educational technology today offers many attractive investment opportunities. Applications of ET in engineering education involve faculty who can be expected to provide both an educator's insight into pedagogical issues and an engineer's skill in organizing and adapting hardware. Perhaps no better proving ground for instructional technology could be devised.

The primary purpose of the study was to provide a critical evaluation of the ET literature regarding applications to engineering education. In conclusion, I will summarize a number of suggestions in the hope that they will serve as stimuli for thoughtful consideration and perhaps even action. In the following paragraphs, the authors' principle suggestions are ranked in order of priority.

(1) The number of talented individuals working with ET needs to be enlarged greatly in order to increase the impact of powerful new delivery systems.

> NSF should maintain its programs which encourage broad scale, diversified development and testing of ET courseware in various media at the local course level. The purpose of these programs should be to involve many more faculty nationwide in meaningful ET activities.

(2) The unique learning experiences provided by combining interactive computing with individual graphical displays should be widely available to engineering students, but are rare in practice today. Courseware in computer-aided design and simulations of computer-aided manufacturing need to be created in all engineering disciplines. The colleges which pioneer in this endeavor will incur equipment costs which, while high now, are likely to decline later, as well as software development expenses. To provide incentives to get more work underway now, it may be necessary to subsidize a first generation of facilities. Follow-up programs several years later, will probably be necessary to assure wide spread availability of computer graphics equipment.

> At least twelve prototype computer graphics centers should be funded in the next two years at selected engineering colleges. These centers will serve as regional models for the organization and operation of interdisciplinary facilities, as clearinghouses for vendors and educators, and as developers of outreach materials for engineering educators nationwide. External funding of these pioneering centers might require only one-third to one-quarter local matching. A second round of facility grants to general availability might involve up to fifty percent matching by colleges.

(3) Videopublishing gives the university a distinctly new opportunity to serve the practicing professional. Coordinating master teacher and existing creative university staffs in video production and computation with all the traditional functions of publishing, requires

new organizations. Early efforts in videopublishing should provide visible models which combine both the scholarly prestige and the entrepreneural spirit of the traditional university presses.

> Several university "videopresses" should be endowed at universities having a strong commitment to continuing education of professionals and the media expertise to set high standards of quality. These new enterprises would provide a creative outlet for faculty everywhere to develop modern instructional programs under the guidance of skilled staff. Private foundation support seems most appropriate here.

(4) Modern communications technologies may one day make extensive resource sharing a reality in higher education. Early efforts should focus on non-threatening domains in order to elicit maximum faculty cooperation. The AMCEE consortium brings together the resources of 22 universities which have major investments in regional ITV systems to provide both graduate and continuing education programs to engineers at their job sites. New communications technologies could best be introduced into universities in a mission-oriented activity such as AMCEE proposes.

> An operational plan to test the cost effectiveness of communications satellites should be funded to provide engineers at their job site with the following educational services: national delivery of graduate credit courses in a coordinated program initially involving ten AMCEE universities; delivery of continuing education short courses; teleconferencing between originating sites to provide for direct faculty exchanges, as well as special seminars and technical meetings. Studies should be undertaken to involve ethnic minority colleges of engineering in activities of their chosing.

(5) Technology transfer with foreign nations wishing to provide opportunities for engineering post-graduate study in the United States

could be accomplished by means of satellite interconnections and cooperative arrangements between AMCEE colleges and foreign universities.

> Engineering educators and government development officials from a number of countries should meet to discuss alternate operational modes and to outline the scope of the activity. Feasibility studies including technical communication systems designs and cost estimates should proceed concurrently in order to provide guidance and realistic time frames.

(6) Campus instructional laboratories are rarely equipped with the powerful new measurement instruments now found in industrial practice. University equipment budgets have not kept pace with the emergence of modern devices. The problem is becoming more acute each year.

> An in-depth study of the equipment problems of colleges of engineering should be undertaken, perhaps by an industrial team sponsored by the National Research Council. Recommendations might include government incentives to industry as well as emergency programs to overcome what has become a massive hardware problem.

(7) The decentralization of instructional computing appears inevitable. This transition will bring many new problems in funding and operation to campus as well as unparallel opportunities to integrate computing into the students' experience.

> Universities should design a number of new programs to expedite the transition to decentralized computing. These diverse efforts might include the sponsorship of the following: "consumers' unions" to evaluate machines and courseware; visiting lectureships; workshops and summer institutes; and media-based "packaged" short courses for in-service training of teachers.

(8) The case study method of instruction is gaining popularity in engineering as an effective way of bringing practical design problems

into the undergraduate curriculum. Television or films have been shown to add realism and a stimulating emotional dimension to an otherwise highly abstract instructional program. However, very little media now exists.

> Private foundations should explore the creation of working consortia or nonprofit organizations to produce high quality films and videotapes in support of case study instruction, especially in engineering design and in professional ethics.

(9) ET has made possible engineering-related programs for students in both rural and inner city high schools. Industrial films giving an orientation to engineering, introductory computer courses, videotape, hand held calculators, and personal computers all have been successfully employed in gaining the interest of ethnic minority students. More effective and universal programs might now be planned based on experiences to date.

> The use of ET in attracting, motivating, and preparing ethnic minority students and others who are educationally disadvantaged in grades 9 through 12 should be extended. A few university based centers could supply materials and information to the many programs which are now sponsored by businessmen and educators regionally.

(10) Decentralization of instructional computing may foreclose the upgrading of university central computing facilities. University-based researchers may find it difficult to participate in the powerful advances being made in super computers.

> The National Academy of Engineering (NAE) should sponsor a feasibility study on the creation of several regional computation centers for engineering research.

(11) The rush to create a consumers' market in ET will probably have a profound impact on learners of all ages. Yet, this survey of the literature uncovered no systematic study of what this may mean, nor how educators and schools may react.

> The NAE should revise its 1974 study on the issues and public policies in ET in the light of the current trends and forecasts in hardware delivery systems.

Mr. **Walgren**. Thank you very much, Dr. Baldwin.

Mr. **Brown**. Dr. Baldwin, will you continue preaching to the choir a little bit here. I have been very much interested in the utilization of technology for continuing education, graduate education of engineers. While I do not have the expertise and the background that you do, I am aware of the success of programs such as you have and at Stanford and other universities. Is there any technical reason why programs of this sort incorporating the very best course ware, continually upgraded to meet the changing conditions of engineering, could not be made available on a wider scale to essentially all of the engineers in the country?

Dr. **Baldwin**. Mr. Brown, you know that we have met with kind of bimodal success and failure. Off campus where the practicing engineer values his time, and where his opportunities and alternatives for live instruction are nonexistent or marginal, use of television has been very welcome—and they have put up with abominably poor programs—but with good content that they needed to know. Face on tube is the name of our game. On the other hand, in the relatively rich campus environment, where live instruction and personal interaction are the expectation of the student—and rightfully so, perhaps—we have not met with similar success in using television and it has to do largely with the recognition, I think, simply that education is a very human endeavor, and humans select from the alternatives that are available.

In the report to be published soon by the National Academy of Engineering, I found some excellent examples, very broadly based examples, very practical examples—to mention one, open laboratory hours. The ability to demonstrate a piece of equipment, or give some safety precautions via a brief, homemade videotape enables the faculty to open the laboratory over a much longer period of time. This may sound kind of homely, but when you are faced with the kind of student numbers we are faced with today, the ability to open the laboratory for more hours than you have teaching assistants is a real advantage.

There are many other opportunities that have by no means been exhausted. Use of educational technology has been a very decentralized and ad hoc thing, and it is extremely hard to make the best of those opportunities, given our current circumstances. The faculty are so pressured by the on-campus student demand that, indeed, meeting our off-campus television commitment turns out be be very difficult. It is only because of the quality, initiative, and enthusiasm of the off-campus students that I think the faculty responds as well as they do.

Mr. **Brown**. I am thinking of the technological possibilities that exist today to transmit from a campus, for example, program material on an interactive basis using a satellite.

Dr. **Baldwin**. Oh, yes. There is no technical reason whatsoever not to, and that would be welcome. As you know, a number of major corporations have definite plans in that direction at this time, both for teleconferencing for their research staffs and for adding educational programs for these staffs. So there is certainly no technical or institutional reason to not do more of that. And in an engineering school there is a very natural link because of our interest in applications between the university campus and the industry. We have no philosophical hangups about those things.

Mr. **Brown**. You remarked that your association had received a grant to develop certain of these programs. Was that from the National Science Foundation?

Dr. **Baldwin**. Yes. It was not for curriculum development per se; it was essentially a grant to help the Association for Media-Based Continuing Education for Engineers (AMCEE) get started, produce its first catalogs, and demonstrate that it had a service to offer industry. The NSF grant was a phased, 3-year declining grant. That grant was the difference between our getting started and not getting started as a cooperating group of schools.

Mr. **Brown**. You are not included in the series of four or five grants that were made last year from the NTIA to aggregate public service uses?

Dr. **Baldwin**. No, Mr. Brown. We cooperated with the Appalachian Community Satellite Network (ACSN) group in the proposal preparation. We found it more difficult to cooperate with them in the delivery of education once ACSN received the NTIA funds.

Mr. **Brown**. I am interested in pursuing the possibilities of further development in this area, and I am seaching for the most opportune way to do that in the current fiscal atmosphere that exists. I am wondering whether the National Science Foundation or some other part of the Federal Establishment might be the best way to support that. Let me ask a question here.

Dr. Drucker, you have suggested the dimensions of a financing problem involved here, and the whole problem of improving engineering education and research, and indicated some ideas about the amount that the National Science Foundation, and possibly the mission agencies should fund. How do you look on the role that industry which provides the jobs, has the needs, makes the profit from these engineers, should play, and how should that be organized? Obviously it is not as easy to get a decision from an aggregate engineering community or engineering enterprise community as it is from the Federal Government. What suggestions do you have both as to sharing and how to harness it to this program?

Dr. **Drucker**. Let me say first that the problem is not one of improving engineering education, it is avoiding a collapse of the engineering education system. That is why I think the Federal Government has a key although a relatively small role. We would expect industry to provide substantially more money. The problem is a multibillion dollar problem. The industrial community has been working with us, has been talking quite vigorously about how they can be of help. In some cases—at my own institution in particular—we have received some sizable sums of money. As sizable as they are, when compared to the problem, they are still very small. But I do have great hope that in the various consortia that are being developed now—and I don't want to use the wrong word in case the Justice Department is listening—the groups concerned about the crisis in engineering education are discussing it. Out of that discussion now going on they will develop mechanisms for providing support. But it is not realistic to expect General Electric to give large sums of money for an activity which may in fact turn out to be more valuable to Union Carbide or vice versa to mention just two members of one of the groups,

I do think that if you send a clear signal that the problem is real and do something about the problem, while you are sending the signal, then I believe the universities in concert with our friends in industry could do a great deal more. Of course, in addition to industry, we need State government assistance for State universities. We need private giving for those in private universities. Total needs are literally billions of dollars—and one is talking here on the order of $100 million.

Mr. BROWN. The climate that we face today is one of a reduced Federal role and the assumption that the private sector will pick this up. In the past that has not necessarily always occurred, but in part it has been due either to a lack of mechanisms or to obstacles placed in the way, or to the lack of broad scale thinking on the part of the leaders and policymakers in both government and industry. The deans of engineering schools have not necessarily been in the forefront of looking at this as an integrated problem for the Nation. They see it in their own perspective. But I am wondering if there is any problem in beginning to bridge these divergent interests, say, through a mechanism like the Industrial Research Institute—which includes basically the major private sector industrial performers—working with the deans of engineering schools and appropriate policy level personnel from the Federal Government, to develop a package in which there is some sharing and then seeking to meet their commitments to an overall program of this sort. That is very complex. It is difficult. It probably would fail in many ways.

On the other hand, the present system is under severe attack, and we are going to have to be looking at solutions.

Dr. DRUCKER. There have been several meetings already with groups of industry people. There will be another meeting at the end of this month in New York City. I would expect eventually that good things will happen.

The problem is that if we wait for that eventuality, it will be too late. This is why I urge a Federal initiative on a small scale to tide us over to the time when the other initiatives can take over.

Mr. BROWN. I think there are many of us here in the committee listening, and probably in the Congress, who would be willing to accept the crisis nature of the problem and would be willing to make the commitment to the initiative you suggest, but who would probably feel that without some indication of mutual sharing of the responsibility, it is going to be difficult.

Dr. DRUCKER. That is why I was a little unhappy to find only representatives of universities testifying before you today on this particular issue. I had hoped that there would also be representatives from some of these industrial groups.

Mr. BROWN. We have several more days of hearings.

Dr. DRUCKER. I hope they will appear before you without us present to share their perceptions with you.

Until a year ago many of the industrial people did not understand there was a real problem because they got Ph. D.'s by paying more. Then they began to make their own individual calculations. Everyone computed—and it is a very simple calculation—that they were going to run out. They found out what we in the universities knew long ago. Then they got excited, and I think they would convey that excitement and that worry to you, and I would hope also convey to you their willingness to do their share.

Mr. **Brown**. You see, the previous administration didn't weigh the dimensions of this problem until quite late, and then they began to perceive there were needs and problems. You heard this appreciation of the need to overcome the adversary relationship which has precluded the kind of cooperation necessary here.

I would hope that this administration wouldn't go too far in the other direction and say we will leave the whole thing to private initiative and the market system, without recognizing we still need this cooperative relationship and the elimination of that adversary difficulty that plagued us in the past.

I think most of us have come to the conclusion that one of the problems of our society competing with the other society is that they really have done a better job of integrating their national goals and working to meet those national goals.

Dr. **Drucker**. I share this view.

Mr. **Brown**. Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Brown.

The hour is late, and I just want to say, as someone who has not given a great deal of thought to this area in the past but who is very interested in it now, that I appreciate the content of what you have said. I hope that we can be somewhat responsive to it. Thank you very much.

[Whereupon, at 5:10 p.m., the subcommittee adjourned.]

1982 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, MARCH 5, 1981

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcommittee met, pursuant to notice, at 2 p.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. Walgren. The committee will come to order

At the outset I would like to grant by unanimous consent permission that photographs may be taken by some members of the interested press. Without objection, permission is granted.

Today is the second of 5 days of hearings on the National Science Foundation authorization. We will be examining a number of issues related to the activities of the Foundation particularly the support of applied research, the new Engineering Directorate, and innovation.

The Foundation has recently completed a reorganization plan that makes the support of applied research the responsibility of all the research directorates rather than just one.

Hearings by this subcommittee in the past Congresses have indicated that basic and applied research are closely related and often mutually supportive. Apparently, the reorganization provides a new means for more closely coupling all of NSF's research. We hope this is done in a way that enhances the pathway of applications development from basic research, and allows the stimulation of basic research that applications work often generates.

The committee is committed to observing closely how well the new arrangement is working in NSF, and will look forward to cooperating with the Foundation leadership in building understanding in the technical community for the new arrangement.

We have also been concerned for a number of years with the relation between research and innovation. NSF has a number of important programs to promote innovation such as the small business innovation research program and the industry/university cooperative research projects program.

Unfortunately, it would appear that these programs and others are slated for major reductions in the fiscal year 1982 budget. I believe these programs and their reduction should be carefully considered, given their relevance to problems our economy is now facing in particular.

Today, for the first time, we are hearing formally from representatives of the Foundation, in particular Dr. John Slaughter, its

Director; and Dr. Lewis Branscomb, Chairman of the National Science Board. We welcome you.

Though we haven't officially received the administration's fiscal year 1982 revised budget, I believe we have enough information to begin discussing a number of the issues and programs on which the subcommittee's final judgments will have to be made. The questions related to the Foundation's applied research, engineering and innovation programs certainly fall into this category.

Hopefully, today will provide us with an opportunity to explore NSF's overall structure, particularly with respect to engineering and applied research, in order to look for ways to move our scientific and technical resources to the support of our economic needs.

Let me ask at this time whether Mr. Brown has any opening remarks.

Mr. **Brown**. No, Mr. Chairman.

Mr. **Walgren**. Before introducing our first witness, I would like to note that we have received some outside statements for the formal hearing record and without objection they will be included in the record at the end of today's proceedings.

So far we have received statements from Dr. Philip Speser on behalf of the Federation of American Scientists, and from Robert A. Cox, the director of the New England Innovation Group. We expect to receive others.

With that I would like to turn to our first panel of witnesses for today, which consists of Dr. John Slaughter, the Director of the National Science Foundation, Donald Langenberg, Deputy Director of the National Science Foundation, Dr. Jack Sanderson, Assistant Director for Engineering of NSF, and Dr. Lewis Branscomb, Chairman of the National Science Board.

Welcome to the committee. We appreciate your being here and any written statements you have will be made part of the formal record. However, instead of reading them you may summarize them, if you wish.

[A biographical sketch of Dr. Slaughter follows:]

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

JOHN BROOKS SLAUGHTER
Director

Dr. John Brooks Slaughter was confirmed by the Senate to be Director of the National Science Foundation on September 23, 1980. He was nominated for the post by President Carter on July 3, 1980.

Before joining NSF Dr. Slaughter was Academic Vice President and Provost of Washington State University, Pullman, Washington. Prior to his appointment to Washington State University, Dr. Slaughter had been Assistant Director of the National Science Foundation for Astronomical, Atmospheric, Earth, and Ocean Sciences, a position to which he was nominated by President Carter on August 31, 1977.

As Assistant Director for AAEO, Dr. Slaughter was responsible for five NSF divisions--Earth Sciences, Ocean Sciences, Astronomical Sciences, Atmospheric Sciences and Polar Programs. The Directorate supports several major research programs such as the Global Atmospheric Research Program, the Ocean Sediment Coring Program, and the Arctic and Antarctic Programs. It also funds and administers a number of major national research laboratories.

Before assuming his NSF position, Dr. Slaughter was Director of the Applied Physics Laboratory and Professor in the Department of Electrical Engineering at the University of Washington at Seattle.

As Laboratory Director since 1975, he was responsible for the direction and management of a research and development program in ocean and environmental sciences and engineering. He initiated new programs in energy resource conservation and development, geophysics, environmental acoustics and bioengineering at the Laboratory. Under his direction, the staff of the Laboratory, a leader in the fields of underwater acoustics, underwater vehicles and physical oceanography, grew from 180 to 240.

Prior to going to the University of Washington, Dr. Slaughter was Head of the Information Systems Department of the Naval Electronics Laboratory Center (NELC) in San Diego, California. In that capacity he was responsible for the management of a 200-person staff engaged in the design and development of Navy command control and communication systems. Under his direction there, a major new emphasis in biomedical engineering was started. He was named Scientist of the Year at NELC in 1965 where he served from 1960 to 1975.

Earlier in his career, from 1956 to 1960, Dr. Slaughter was employed by the Convair Division of General Dynamics Corporation in San Diego where he worked on the development of missile flight instrumentation and telemetry equipment.

Dr. Slaughter was born in Topeka, Kansas, in 1934 and earned a Bachelor of Science degree in electrical engineering at Kansas State University in 1956. He earned a Master of Science degree at the University of California at Los Angeles (UCLA) in 1961. He also was awarded a Doctor of Philosophy degree in engineering science at the University of California at San Diego in 1971.

Dr. Slaughter has written widely in his field and is a member of several professional organizations including Eta Kappa Nu, the honorary electrical engineering society; Sigma Tau, the honorary engineering society; and the American Association for the Advancement of Science (AAAS). He has been Editor of the International Journal of Computers and Electrical Engineering since 1977. He is also a Fellow of the Institute of Electrical and Electronic Engineers (IEEE).

He served from 1968 to 1975 as Director and Vice-Chairman of the Board of the San Diego Transit Corporation, specializing in policy matters related to transit planning and technology. He was a member of the affiliate engineering faculty at San Diego State University from 1963 to 1965 and established graduate courses in discrete and optimal control systems. He was appointed to the San Diego Chamber of Commerce Energy Task Force in 1974 to advise on technological approaches to energy conservation.

Dr. Slaughter has been active in efforts to encourage minorities to pursue careers in science and engineering and has played a strong role in urging educational institutions, industry and government to take more aggressive steps to improve opportunities for minorities in those fields. In 1976, he was appointed a member of the National Academy of Engineering Committee on Minorities in Engineering.

Dr. Slaughter is married and has two children.

September 1980

STATEMENT OF DR. JOHN B. SLAUGHTER, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. **Slaughter**. Thank you, Mr. Chairman.

Dr. Lewis Branscomb, Chairman of the National Science Board, is scheduled to join us.

You have already mentioned that I am accompanied by several members of my staff. At the table with me now is Dr. Branscomb, who has just arrived. In addition, I want to introduce Dr. Donald Langenberg, Deputy Director of the National Science Foundation, and Dr. Jack Sanderson, Assistant Director for Engineering and Applied Sciences, soon to become our new Assistant Director for Engineering.

This is my first opportunity to formally address a committee of the U.S. Congress since being named Director of the Foundation. I am particularly pleased to have that opportunity to appear before you this afternoon.

The National Science Foundation has had a long history of support from this subcommittee. We are particularly mindful of the continued support from Congressman George Brown, who has done so much in his role on this subcommittee in the past. We are very pleased, as I said earlier, that Congressman Brown has chosen to remain involved with the subcommittee's activities. I understand that Mr. Ertel, another member of the subcommittee in the previous Congress, is still a member of the subcommittee. He also has done much to help us with issues in science policy.

As I indicated in the informal hearing held before the subcommittee about 2 weeks ago, the National Science Foundation is truly a unique organization. NSF's responsibilities, according to the charter of the Foundation established in 1950, require it to be concerned with the health of all scientific and engineering disciplines. This mandate is in marked contrast to those of all other agencies, each of which has a particular mission and narrower responsibilities the National Science Foundation must structure its support of research more broadly.

Because of the unique responsibilities of the Foundation, it was structured in a way to enable it to provide the broad support required. A National Science Board was established as the policymaking body of the Foundation. The Board consists of 24 members, each appointed by the President, with confirmation by the U.S. Senate, to terms of 6 years each. As Director of the Foundation, I, too, am appointed by the President to serve for a term of 6 years. As such, I am the 25th member of the Board in an ex officio status.

The Board elects its Chairman and Vice Chairman, each serves for 2 years. Dr. Branscomb, as I indicated earlier, is the present Chairman of the National Science Board. He is also a vice president and chief scientist of IBM and a former Director of the National Bureau of Standards.

I would like to interrupt my testimony at this point to allow Dr. Branscomb to comment on the role of the National Science Board, the Foundation's activities, and the Board's views on some major issues of science and technology.

[A biographical sketch of Dr. Branscomb follows:]

DR. LEWIS MCADORY BRANSCOMB
Director, National Science Board
National Science Foundation

Dr. Lewis Branscomb is currently Vice President and Chief Scientist of IBM Corporation in Armonk, New York. Since 1980, he has been the Chairman of the National Science Board, the policy-making body of the National Science Foundation. He was nominated by President Jimmy Carter in 1979 to serve a six-year term on the Board.

Born in Asheville, North Carolina in 1926, Dr. Branscomb earned an A.B. degree from Duke University in 1945 and completed his Master of Science and Ph.D. degrees at Harvard University.

During 1965-68, Dr. Branscomb was a member of a Presidentially-appointed Science Advisory Council and also served on the President's National Medal of Science Committee in the Nixon Administration. His scientific interest is in physics, having taught on the university level. From 1962 to 69, he was the Director of the National Bureau of Standards.

STATEMENT OF DR. LEWIS BRANSCOMB, VICE PRESIDENT AND CHIEF SCIENTIST OF IBM, INC.

Dr. **Branscomb**. Thank you, John.

I apologize for being late, Mr. Chairman. The Lord generously decided to deliver much needed water to New York but delivered it in an exceedingly inconvenient form.

I would like to be quite brief and speak informally. I will not succumb to the temptation to summarize too broadly the problems faced by the United States, but I will try to persuade this committee to enhance the level of technology practiced in our economy, which is the key to improvement in international competitiveness. You have heard a great deal of testimony and indeed the committee's own reports document the facts quite clearly.

I do not believe that any thoughful American, in or out of Government, of whatever political persuasion, contests the need to reverse the trend of the last decade, which has seen our standard of living threatened, our growth and affluence eroded, and our acknowledged leadership in science and industry put to serious challenge by our allies as well as potential opponents.

The technological achievements of Japanese industries define for us the job that lies ahead for every American. It does not detract from their achievement to say that they have done it using business and engineering skills derived predominantly from the American model, and that they make full use of America's scientific knowledge base. This only tells us that we have no one to turn to but ourselves. Their success is not, as some believe, due to cultural advantages.

Scientific and engineering genius are not foreign to American culture. They are as American as Benjamin Franklin and Thomas Jefferson. Agile and innovative business leadership is not a unique Japanese capability. Xerox and IBM are American companies, so are Cray Computer, Apple Computer, and Genentech.

The Japanese are challenging us with American copies. The trouble is their copy is beginning to look more American than does the original thing.

Ten days ago the National Governors Association held a conference on innovation and technology to which this committee's chairman and ranking majority members made insightful contributions. A number of governors contributed, and the focus was on technology as the key to revitalization in their States in the 1980's. One comparative description of the United States and Japan struck me as telling much of the story; I will read just a few sentences from the staff report to that conference.

> In the United States over the past ten years, the production of electrical engineers has steadily declined to 17,000 a year while the production of lawyers has steadily increased to 33,000 a year. Out of every 10,000 citizens in Japan, only one is a lawyer and three are accountants, while in the United States twenty are lawyers and forty are accountants. Of the same group, Japan has 400 engineers and scientists, the United States has 70.

I think all Americans will agree that there must be a readjustment of national priorities, and there is a lot of work to be done. There are differences about those priorities; and, more deeply, there are differing views on what the Federal Government's role is. However, the election sanctioned the administration's effort to attempt a redefinition of that role in collaboration with the Congress.

I believe such a redefinition is not only being forced on us by the realities of inflation and Federal deficits, but also by a maturing understanding of the dynamics of our scientific, engineering, industrial, and educational sectors. None of these can function effectively if any of the others are in serious trouble. Today, all of them are at least seriously challenged, if not yet in serious trouble. The Federal role is nevertheless different in each.

The National Science Board is charged by the Congress with a concern for the health of America's basic scientific and engineering capabilities. We intend to spend increasing fractions of our time attempting to balance ever more sharply priorities for NSF's major research investments in the face of budget stringencies. But for the last 2 years we have also focused our debate on policies that will help the Foundation sort out its role in engineering and applied science in relation to the economy in generally.

The National Science Board has encouraged the Foundation to seek stronger ties between industrial and university research. It is attempting to define better the boundaries of appropriate NSF activities in areas of science and engineering that touch most closely on technologies of commercial importance.

Let me not take the committee's time today for a recitation of these debates. My own views were amply documented in my testimony to this committee on the proposed National Technology Foundation last fall and to the Senate Budget Committee on January 26, 1981. In a recent address at the National Bureau of Standards, where I was speaking strictly for myself and not for the Foundation or the Board, I went into these points in some detail.

[The text of Dr. Branscomb's address of the National Bureau of Standards appears at the end of this day's proceedings.]

Dr. Branscomb. I would like to assure you that, notwithstanding the diverse composition of the National Science Board between different fields of science and engineering and between academia and industry, the Board has been consistently unanimous in conclusions on policies for managing basic and applied research and on the need to focus additional attention on engineering.

The management of these policies is in very capable hands. Dr. Slaughter and Dr. Langenberg know from their own personal careers in science and engineering that the vitality and the utility of research benefits from involvement in both long- and short-range outlooks and the interplay between speculative and concrete ideas, applications of science tests and definite ideas to transform the hard-to-grasp new concepts into what we call "commonsense." The deepest exploratory work defines the limits of validity of that common sense and thus defines whole landscapes of opportunities from which future generations may benefit. All of this fundamental useful work is as essential to industrial progress as it is to an education for life in the twenty-first century. It is not only compatible with the national trend which might be called "back to basics;" it is a policy that reflects all we have learned about how to make progress at the frontiers of science and engineering, how to train people equipped to advance and exploit that knowledge and how to support industrial progress without intruding on work best left to private investment.

That policy reflects a limited Federal role, and it suggests that we forego many areas that have been suggested to us in the past, but which may be more appropriate for the Department of Commerce or other agencies or perhaps conceivably not appropriate for the government at all.

It does not, unhappily, contain a prescription for solving budgetary pressures on that segment of the scientific enterprise for which the Federal Government has a unique responsibility. We have not yet caught up in our efforts to reverse a long decline in American science since the sixties, and we have only begun to address the crisis faced by our engineering schools and reflected in serious shortfalls of both people and technical knowledge in American industry.

The right Federal programs in science and engineering are not only as important to this Nation's security as is defense spending, they are the cornerstone on which our military and economic security rests.

The National Science Board knows the country cannot afford to do more than a select fraction of the important and valuable things the technical community has in view. We are prepared to step back and take stock of assumptions that have guided our priorities in the past. We did this in engineering and applied research in 1980. Our study of our activities in science and engineering education is in progress, and the Board will have a full discussion of it soon.

We have initiated a Board discussion of the biological behavioral, and social sciences. I hope our work will prove informative and useful to this committee, as well as supportive of the National Science Foundation's effectiveness.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Dr. Branscomb.

Dr. Slaughter.

Dr. SLAUGHTER. Thank you, Mr. Chairman.

To continue, I would like to talk a few minutes about how the National Science Foundation does its job, a little more about its structures and procedures.

The Foundation does its work primarily through grants to colleges and universities as research performers. We have no research laboratories of our own. Consequently, we have a relatively small staff, about 1,200 persons in all; about a quarter of these are professionals in science and engineering.

Our staff evaluates somewhere in the neighborhood of 26,000 individual proposals each year; we support somewhat less then one-half of these. In carrying out our activities, we will continue to require the support of many scientists throughout the country, outside experts who constitute our system of peer review.

Last year more than 40,000 scientists, engineers, and educators were involved in assisting us with a review of the many proposals that we receive. Most of this work is done by mail on a proposal-by-proposal basis; in some cases and in some disciplines we assemble panels of experts to come in and look at a number of proposals.

It was mentioned earlier that we had gone through a reorganization. That reorganization had a number of implications for engineering and for our methods of managing both basic and applied research.

I would like to spend just a few moments discussing that.

NSF is organized into seven directorates; each of these is headed by an assistant director. Four of these directorates are organized along scientific lines. One of these handles a number of scientific programs that cannot be categorized by individual disciplines. Another directorate is concerned with science and engineering education and the seventh with administrative matters.

The reorganization that we announced and that will take effect on March 8th realigns our program structure and creates a new directorate for engineering in place of the previous directorate for engineering and applied sciences. This represents a rather substantive change in the way that the National Science Foundation addresses the question of supporting engineering research.

The National Science Board last summer asked the Director and the staff of the Foundation to conduct a study concerned with how the Foundation supports both basic and applied research.

The study indicated a number of important things. First of all, I indicated that the traditional distinction between basic and applied research is often a forced and artificial distinction. We believe very strongly that virtually all good research is potentially applicable.

There are a number of examples that can be stated here. For example, one needs only to think about the discovery of DNA, where that basic research lead very quickly to some applied research and a very important new technology. It has tremendous implications for all of us.

On the other hand, one can think of applied research that has lead to significant basic research, for example, the development of radar and the development of penicillin. It has become increasingly clear to us that the terms "basic" and "applied" are oversimplified and they are oftentimes misleading labels for parts of a very complex process.

Over 100 years ago Louis Pasteur indicated there does not exist a category of science to which one can give the name "applied science". These are sciences and applications of sciences bound together as the fruit of the tree that bears it. I think we have found that to be true today.

We also see that the distinction between basic and applied research is not necessarily a function of the institutional setting in which the work is done. Good basic research is conducted in industrial organizations as well as in the universities, just as good applied research is conducted in both of these settings.

We believe very strongly that our charter for supporting good research means that we support quality research whether it is categorized as basic or whether or not it is categorized as applied. Our responsibility, our top priority, is to look for quality research.

We operate on four principles. Most of the work that we support is work that is proposed by an investigator. It is research that is proposed to the Foundation by someone at a university or a research organization proposing we provide some support for a project that he or she feels would represent an advance in knowledge. We support only research with potential for making significant contributions to the knowledge base.

Three, we attempt to assure both quality and objectivity in the work that we support by asking peer reviewers to examine the proposed activities.

Finally, we insist that the results of the research be widely disseminated. We believe it is very important to recognize that both basic and applied research can fall in these categories. We intend to be concerned with those labels only for the purpose of monitoring our performance, to be sure we do in fact provide support to quality research which falls in either of these two categories.

Our new approach to supporting applied research is one of seeing to it that each of the disciplinary research organizations in the Foundation handles both basic research and applied research, rather than having the applied research relegated to a separate organization.

We intend to see that this works. It may require some changes in the way in which we do our peer review and in the way in which we handle individual proposals. However, we believe it is very important to recognize that the National Science Foundation believes it is important to support both basic and applied research in our activities.

There is a great deal of talk now about innovation. Dr. Branscomb mentioned it in his very cogent comments concerning the status of innovation in our country. I will not repeat nor do I need to repeat what he has said so much better concerning the advances of the Japanese in areas that heretofore had been unassailable insofar as American leadership is concerned. We saw that in computers, communications, microcircuits, and in many other fields.

The National Science Foundation has devoted considerable attention to all of these matters and is quite concerned about it. We believe, for example, research and development have close connections with industrial innovation and productivity.

We believe that supporting highquality research is an essential ingredient of our country's ability to improve our innovation and our productivity.

We are concerned about the fact that a decline in the rate of increase of our knowledge can in fact be one of the reasons that we have seen a decline in our productivity during the 1970's.

Dr. Branscomb has spoken out a number of times on the importance of a strong research and development base if in fact our country is to have a stronger role in terms of productivity and innovation.

Basic research is unquestionably a very key component of our country's ability to strengthen our productivity and innovation.

The vice president for research and development at Westinghouse, just last week said, "The organized pursuit of knowledge of basic research must continue to be the basic fuel of innovation."

NSF is responding to this by establishing a new division of industrial science and technological innovation, whose goals will be to work very strongly in this area of improving innovation by supporting quality research.

There are four closely coordinated programs that will be managed in that particular division, an industry-university cooperative research program, a small business innovation research program, industry-university cooperative research centers, and an innovation processes research program.

Each of these programs will have a key responsibility in carrying forth our charter in supporting the best in basic and applied research as it affects our Nation's ability to increase its innovation and productivity.

I will not go into any detail at the moment concerning the elements of those programs. We can respond to those if in fact there are direct questions.

Mr. Chairman, I would like to end my comments by saying that the National Science Foundation believes that in the establishment of a new directorate for engineering, as I indicated will be taking place next week, we will be giving the same significance to engineering research as we do to the other major areas of research in the National Science Foundation.

We believe that research support in areas such as microelectronics, mechanics, and catalysts, are key elements of a strong research posture in the United States. We are very concerned with the critical needs of our universities today in educating engineers, the fact that there are a large number of unfilled faculty positions, and that the situation does not appear to be improving soon.

We are concerned about equipment in our engineering research laboratories and universities and instructional equipment for training young engineers.

We believe the NSF can and will be able to do something to help correct these problems. We have a program which has been concerned with helping young new engineering faculty members begin programs in engineering research. We have supported about 110 awards each year in this program. We think this is a very important program in helping to strengthen our engineering research program.

We are enthusiastic about our commitments to engineering. We believe that we are taking the proper steps to address the critical needs that face this country in that area.

All of us here will be very pleased, Mr. Chairman, to answer any questions that you or members of your committee may have, either on the testimony that we have given or on any other issues that may have been raised.

Thank you.

[The prepared statement of Dr. Slaughter follows:]

Statement of

DR. JOHN B. SLAUGHTER
Director, National Science Foundation

before the

Subcommittee on Science, Research and Technology
U.S. House of Representatives
March 5, 1981

Mr. Chairman and Members of the Committee:

It is a pleasure to appear before you this afternoon to begin discussions on the proposed programs of the National Science Foundation for 1982. This is my first formal appearance before the Congress as Director of the Foundation. I would like to say at the outset that I value highly the chance to meet regularly with this Committee, and to work together with you in developing the best possible programs for the Foundation. We have benefited greatly from interaction with this Committee in the past, and I look forward to continuing what has always been a most fruitful relationship. I wish especially to thank Congressman George Brown for his deep interest in and unstinting efforts on behalf of science and the National Science Foundation as Chairman of this Subcommittee in the last Congress and as a particularly hard working member for a number of years prior to that. I am delighted to see him among those serving on the Subcommittee in this Congress. Both he and Mr. Ertel, another member who served on this Subcommittee in the last Congress, have done much to help us deal with complex issues of science policy.

Before turning to the specific matters of interest today, Mr. Chairman, it might be appropriate for me to say a little about the fundamental mission and procedures of the Foundation.

The Foundation is a unique organization. It is different in important ways from all other Federal agencies, because it was established to carry out the unique mission to support research and to be generally concerned with the health of all scientific and engineering disciplines. This is in contrast to other agencies with substantial research efforts, for each of these agencies has a particular mission to perform, and must structure its research program accordingly.

At the time the Foundation was established, it was recognized that it needed to be responsive to both the President and Congress, and also to the scientific community. Consequently, the National Science Board was created, consisting of twenty-four members, appointed by the President with confirmation by the Senate, who serve on a part time basis for terms of six years. As Director, I am also appointed by the President, and serve at his pleasure, although normally for a term of six years. I also serve ex officio as the twenty-fifth member of the Board.

The Board elects its own Chairman and Vice-Chairman, who serve two year terms. I am pleased to have with me today Dr. Lewis M. Branscomb, the present Chairman. Dr. Branscomb is Vice

President and Chief Scientist of IBM, Inc., and a former Director of the National Bureau of Standards. With your permission, Mr. Chairman, I would like to interrupt my testimony at this point and ask Dr. Branscomb to provide some additional information on the National Science Board and its view of major current issues in science and technology.

Dr. Branscomb's statement

Mr. Chairman, before passing on to a discussion of the specific issues we are dealing with today, I would like to say a bit more about our structure and procedures. The Foundation does its work primarily through grants to colleges, universities, and other research performers; it has no research laboratories of its own. It therefore has a relatively small staff, about twelve hundred persons in all, including about three hundred professionals who make the initial decisions on individual proposals. They evaluate about 26,000 individual proposals each year, a little less than half of which are eventually supported. Even three hundred scientists cannot be expert in all scientific areas, however, and thus in nearly every case we ask outside experts, scientists who are actually working in the specialized area represented by each proposal, to help us evaluate it. This is the system of "peer review" which is at the heart of the Foundation's decision making process. Last year more than 40,000 scientists, engineers, and educators were involved. Much of this work is done by mail on a proposal-by-proposal basis, although some programs assemble panels to consider a group of proposals at one time. Different programs use one or another or a blend of these two approaches, depending on the character of the proposals and the field in question. Except for members of standing panels which meet regularly and consider large numbers of proposals, nearly all of our reviewers serve without pay.

Reorganization: Basic and Applied Research

The Foundation is organized into seven Directorates, each under an Assistant Director. Four of these follow scientific disciplinary lines, one deals with scientific programs that cannot be classified by discipline, one handles educational programs, and the seventh takes care of administrative matters. We have just completed several months of study and planning concerning the best way to organize ourselves. We have recently announced a reorganization that realigns our program structure significantly, and creates a Directorate for Engineering in lieu of the previous Directorate for Engineering and Applied Sciences.

Last June, the National Science Board asked the staff to undertake a study of the organizational implications of charging each directorate of the Foundation with responsibility for supporting both basic and applied research within its disciplinary range. We began that effort immediately. By November we were convinced that we could more effectively carry out our responsibilities if we established a Directorate for Engineering in lieu of the then existing Directorate for Engineering and Applied Sciences, and simultaneously assigned applied science responsibilities to what have been known as the "basic" research directorates.

Our study led us to the conclusion that the traditional distinction between "basic" and "applied" research is often forced and artificial. Virtually all good research is potentially applicable. We all recognize that it has been the source from which most modern technologies have developed. One need go back no farther than the discovery of DNA to find basic research that quickly led to applied research and a technology of potentially enormous social and economic importance. One can equally readily think of examples of nominally applied research that opened up many new areas of basic research. It increasingly appears that the terms "basic" and "applied" are oversimplified and sometimes misleading labels for parts of a very complex process.

We can also see that the distinction between basic and applied research is not necessarily a function of the institutional setting in which research is done. Thus, many industrial research laboratories, where management is primarily interested in applications, have found it profitable to do very fundamental, or "basic" research, and do not find the distinction between basic and applied research useful. And we have also seen university investigators, with primary interests in doing basic work, turn to very practical and economically important tasks.

To say that the line between basic and applied research is indistinct, however, is not to deny important differences between types of research. The Foundation's mandate to support research in all the sciences and engineering is a broad one, but we provide only a small part of the total resources made available by the Federal government for research. This leads us to a resource allocation strategy based not on specific well-defined missions but on general principles relating to the character of scientific and engineering research, and to the health of science and engineering:

1. As a rule, the Foundation supports research proposed by the investigator. Thus, opportunities to uncover new knowledge and new applications of knowledge are identified and pursued by those best placed to do so.

2. The Foundation supports only research with potential for making significant contributions to our knowledge base, because only such research has broad potential applicability.

3. The Foundation attempts to assure both quality and

objectivity by basing our selection process on independent technical review by peers.

4. The Foundation insists that the results of the research we support be widely disseminated through the open technical literature.

Having noted how hard it is, in practice, to distinguish between basic and applied research, it remains to be emphasized that we recognize the need to continue making the distinction, for purposes of monitoring our performance, for some time to come. We will continue to classify proposals as being either basic or applied in character, or some mix of the two. We have developed an accounting system which will allow us to monitor applied research activities in all of our research programs, and we will report regularly to you as our experience with the new system develops.

There will also need to be changes, over time, in the makeup of advisory committees and review panels, and to some extent in the mix of skills among our program officers. The aim will be to insure that we have, in all the groups that are concerned with the selection of proposals for award, a broad understanding of the problems and opportunities in basic and applied work in each disciplinary area. It will take time and attention to achieve this, but I am confident that we can do it, and that the result will be a fruitful union between the two approaches.

Technological Innovation and Research

In recent years we have all become concerned with the pace of technological innovation in the U.S. and increasing foreign competition in technologically sophisticiated products. I am thinking of television and stereo equipment, self-focusing cameras, home video recorders, and other precision products. As Dr. Philip Abelson, the editor of Science, has observed, the Japanese are also mounting a vigorous challenge in areas in which the American lead at one time had seemed unassailable -- computers, communications, semiconductor microcircuits, robotics and others. In the span of only three years, Japanese companies have taken over 40 percent of the world market for 16,000-bit random access memory chips, a key component of modern computers. Hewlett-Packard Co., one of the three largest users of these chips in the United States, reports that the Japanese devices are superior in several respects to those from American sources. There are fewer failures during inspection, production, and use by customers, and therefore, warranty costs are lower.

The NSF has devoted considerable attention in the last few years to this general problem, and has started a number of new experimental programs. Some of these have been quite successful, and have served as models for similar activities in other agencies. These programs are also coming into sharper focus within NSF, partly as a result of our recent reorganization. I am happy to have an opportunity to discuss this area, because it is a good example of our ability to anticipate problems and opportunities.

Research and development have a direct relationship to industrial innovation, on the ability of industry to compete effectively in world markets, and hence on the employment and standard of living of Americans. It also affects the ability of our society to find solutions to problems such as energy and effective defense systems.

A growing literature makes clear that research of the highest quality is an essential ingredient if we are to meet these problems effectively. A part of the decline in productivity in the 1973-76 period must be attributed to a decline in the rate of increase in our knowledge, and Edwin Mansfield has found that there is a direct relation between the amount of basic research carried out by an industry or firm and its rate of productivity increase. Just a few weeks ago at a hearing convened by the Senate Budget Committee, three representatives of the private sector, including Dr. Branscomb, each stated in different ways that Federal support of university research is a critical element in the maintenance of this country's lead in the electronics industry.

Much of the research that goes into the creation of new products and production techniques, of course, is the proper responsibility of private industry, which spends very large amounts, mainly for relatively focused applied research and for product development. But underlying these very large expenditures is broadly ranging research of the most fundamental nature in all the natural sciences and engineering. The time scale for application of this research is generally longer than that of research supported in industry, and it is generally harder to foresee the ways in which that application will be made. But there is no doubt that the application will be made. There is no doubt that, in general, it is research of this most fundamental sort, in the sense that it is aimed at better understanding of the most fundamental physical processes, that makes possible research in industry that can be applied on shorter time scales. As the Vice President for Research and Development at Westinghouse Electric Corporation said at the 40th presentation of the Westinghouse Science Talent Awards, "The organized pursuit of knowledge, which is called basic research, must continue to be the basic fuel of innovation." Most of NSF's activity in support of this fundamental research takes place in the regular research programs, not the programs that I am about to describe. It is worth emphasizing that it is every bit as important to innovation in the long run, as the programs that are focussed more directly on the problem.

With respect to our specific activities in this area, let me begin by pointing out that we have just taken a major strategic step as a part of the reorganization that we have just announced. We are establishing a new Division of Industrial Science and Technological Innovation that will bring together, for the first time, the various specific programs designed to further industrial innovation. It is expected that this administrative change will strengthen the managerial attention, oversight, and focus provided for such programs. In turn, this will enable us to better assess what we are accomplishing.

Our goal of contributing to the improvement of U.S. technological innovation, and thereby to the products and services available to the public, will be approached by supporting research in four closely coordinated programs. These programs are:

- The Industry-University Cooperative Research Projects (IUCR) program, which stimulates the development of linkages between university and industrial research by supporting joint industry-university research;

- The Small Business Innovation Research (SBIR) program, which supports high-risk research by small businesses oriented towards science and high technology to stimulate technological innovation;

- The Industry-University Cooperative Research Centers program, which helps establish university centers, supported jointly with industry, which can conduct research in specific areas that are closely related to industrial needs; and

- The Innovation Processes Research program, which supports and conducts studies and analyses on innovation processes, practices and mechanisms, in order to improve the information base for action by NSF and others.

The Industry-University Cooperative Research program supports collaborative research projects in science and engineering. About half the funds support projects in engineering; the other half supports projects in materials research, chemistry, physics, computer sciences, and biology. In every case, funding is provided partly by IUCR and partly by the relevant NSF disciplinary research program.

The program supports high quality research that explores the scientific basis for new technological possibilities, or addresses important problems in current technologies, and that involves strong collaboration between university and industrial scientists and engineers in performing the research.

One project, jointly supported with the Chemistry Division in NSF, has advanced basic chemical knowledge about the dynamics of electron transfer in oxygen reduction, and has provided a new direction for seeking efficient catalysts to make the hydrogen-oxygen fuel cell a practical and economic possibility. The research was performed collaboratively by scientists at Stanford University, California Institute of Technology, and Hercules, Inc.

Another project, jointly supported with the Chemical and Process Engineering Division of NSF, has demonstrated the engineering feasibility of combining the two steps of a chemical reaction by catalysis and subsequent separation of the reactant products, into a single step in a device known as a selective membrane chemical reactor. In this new biotechnology, the development of continuous processing technologies is important because they allow the use of genetically designed organisms. The membrane reactor, created in collaboration between scientists at the University of Pennsylvania and at General Electric Company, provides one possible technical approach to this problem.

The NSF Small Business Innovation Research (SBIR) program encourages small business firms to submit research proposals which have a high potential for leading to significant industrial innovations.

The program operates on a three-phase concept for each project. In Phase I, competitive awards of approximately $30,000 are made to determine the technical feasibility of proposed research projects. Proposals are submitted in response to an annual program solicitation, the fourth of which is currently in progress. Each solicitation lists a broad range of topics which are eligible for support. We expect to receive over 500 proposals in response to this year's solicitation.

Those projects which appear most promising are selected for Phase II awards, which average about $200,000 and can run as long as 24 months. Phase II is designed to allow in depth research leading, if successful, to a technology which is ready for commercial development. Completion of Phase II marks the end of NSF support.

Phase III is conducted with private funds, and leads, if successful, to a commercially marketable product. Typically support is provided by a venture capital firm or a larger manufacturer, who is willing to come in because the previous work in Phases I and II has reduced the risk of technological failure. Although not a requirement, preference for Phase II awards is given to projects which have a commitment, contingent on success in Phase II, of private funds with which to pursue Phase III development.

The program is designed to provide incentives for small firms and to simplify the Federal proposal process. It supports projects that, because of the high risk involved, could not attract private investment during the early research phases. But it does not substitute public funds for private funds in the later development phase.

All proposals receive peer review as part of the evaluation process. We are also continuing our past practice of conducting regional conferences to acquaint small business entrepreneurs with our program as well as possible opportunities for funding by other Federal agencies.

The success of the program has been substantial, both in terms of the response of the small business community and in terms of the availability of private support for Phase III. Since the inception of the Small Business Innovation program in 1977, participating firms have more than doubled their employment since submitting their Phase I proposals. Private investment in the 21 firms receiving Phase II awards as a result of the first solicitation is now about $9 million.

The Industry-University Cooperative Research Centers are jointly supported by NSF and industry and are responsive to industry's research needs as well as university research interests. They deal with research on techniques and processes with broad applicability within an industry, rather than specific products. The objectives of each center are: 1) to perform research that is compatible with university objectives and meets industry needs, and 2) to become self-sufficient through support by industry in 3 to 5 years. Research programs of centers capitalize on the university's scientific and engineering expertise and support the interdisciplinary activities necessary to meet the industry's research needs. NSF and industry's joint support of centers encourages the university to develop a broad-based research program responsive to the scientific needs of industry. As the research programs mature, industry support increases, while NSF support decreases and is eliminated after a 5-year period.

These centers generally comprise semi-autonomous university research groups focusing on industrial research needs. Recommendations on the focus of the research programs are made by advisory boards composed of representatives of supporting companies. The centers' research directors consider these recommendations in the light of the university objectives and capabilities to conduct a research program that meets the needs of university researchers and the supporting industries.

Centers are initiated only when there is significant cost-sharing by companies and broad industrial interest in potential growth and self sufficiency. An example of one of these centers is the Center for Research on Polymers at the University of

Massachusetts Amherst Campus. The Center organizers received a one-year grant to plan a research program. Based on the results of the planning grant, the Center was initiated in 1980 to conduct research on preparation and solid properties of polymers. Initial industrial sponsors, which provide more than half of the center's support are: Allied Chemical; Alcoa; Arco; Celanese; Dow Chemical; Du Pont; Exxon; General Electric; Kenndall Co., Colgate-Palmolive; Eastman Kodak; Monsanto; Union Carbide; and Westinghouse.

The last program in this area is a small Innovation Processes Research program, which supports research and analyses to improve understanding of the processes by which technological innovation occurs and how those processes are affected by Federal actions. One example is a study gathering data from several venture capitalists to identify how they make decisions concerning support of small high-technology firms. The intent is to determine obstacles to the acquisition of venture capital by such small firms, and the implications for Federal programs.

I hope in this discussion of these technological innovation activities I have been able to convey NSF's ability to anticipate new needs and react in a thoughtful, flexible and useful way. I am very excited about these activities, which have my full support.

Engineering

The final area that I would like to comment on today is engineering. Engineering activities play an important and vital role in U.S. industries at home and abroad. Engineers innovate by translating scientific understanding into new industrial capabilities of economic benefit to the general public.

Despite budget severity, NSF has recognized the importance of engineering research by strengthening the engineering budget during the past two years. NSF has also strengthened the internal organization by creating a new Directorate for Engineering, now one of the four major research directorates. This NSF organizational change gives comparable status to engineering and scientific research.

This is more than a cosmetic change. NSF's commitment to engineering research is continuing in the FY 1982 budget you will receive next week. The Engineering Directorate is moving to broaden its base of research and equipment support, with emphasis in areas such as microelectronics, catalysis, and mechanics, where there is the greatest sense of potential opportunity.

At the same time, applied research activities continue to be an important part of the Engineering Directorate. You heard yesterday from Jack Sanderson about the earthquake program.

Others, such as the Research and Development to Aid the Handicapped program also continue as important elements in the engineering programs.

The Engineering Directorate continues to support vigorously new engineering faculty members through its engineering research initiation grant program. This provides the opportunity for newly appointed professors to start research activities. The program indirectly provides an incentive for retention on faculties of these new professors. This year the Engineering Directorate will award about 110 of these research grants.

In recognition of the shortage of advanced engineering research instrumentation, the Engineering Directorate continues to provide support for specialized engineering research equipment. Proposals for equipment compete with engineering research proposals, but we do attempt to provide universities and colleges with their most urgent equipment needs.

Mr. Chairman, I recognize that there are many things to be done beyond the realm of science and engineering to strengthen the productivity of the United States, and that there are sacrifices in all parts of the Federal budget. But I am enthusiastic about our commitments to strengthen engineering, research in the natural sciences, and programs focussed directly on innovation. I believe the Foundation's budget for FY 1982 is responsive to the country's needs, and that it places its emphasis in the most important areas. I urge your support of the entire program.

Thank you for the opportunity to present my views. We will be happy to try to respond to your questions.

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Mr. WALGREN. Thank you for your testimony.

Mrs. Heckler.

Mrs. HECKLER. I must say I enjoyed the testimony very much. It poses an interesting situation to the Nation. However, I think foremost in my mind at the moment is the regional significance to New England. That is the future of the New England innovation group which has had some considerable success. It has been effective in dealing with local governments, in bringing new engineering technology to local governments, and played a very instrumental role in energy conservation in a country that is very energy deficient.

I wonder what the future of this program will be, what your approach is, and what will this program provide?

Dr. SLAUGHTER. We share your appreciation of the many contributions made by the innovation groups. Certainly one of these is the New England innovation group, which has very strong leadership.

The current planning for future support of some of the programs in NSF's Intergovernmental and Public Service Division indicates that there will be some severe cuts in those areas, and that the innovation groups will be seriously affected by these reductions.

It is our belief at the moment that NSF will have to defer some of the initiatives that have been started under this program. NSF will reexamine those programs to see what things can be accomplished within the budgetary outlook for the future.

I do not anticipate that NSF will be able to carry those programs ahead in the current fiscal climate without major changes. Their work has been significant, at some point in time I hope that NSF will be able to continue those programs.

Mrs. HECKLER. I am unclear as to exactly what is your final analysis of the future of the program. Give us at least an interim analysis. You seem to be hopeful in the longer term and I would like you to restate what exactly you see at the transitional level of activity, considering the budgetary cutbacks and considering the particular programs?

Dr. SLAUGHTER. Specifically, insofar as the fiscal 1982 budget is concerned it is unlikely those programs will be supported.

Mrs. HECKLER. In other words, they will be totally eliminated?

Dr. SLAUGHTER. That is correct.

Mrs. HECKLER. This is a judgment in which you concur?

Dr. SLAUGHTER. Yes I believe the work is important. I believe that in the framework of our core programs in basic research, they do not have the same priority. I support the basic research programs contained in the budget we have presented to you as having a higher priority.

Mrs. HECKLER. If support by NSF is cut off, what is the possibility of the immediate acquisition of some of these programs by the private sector or State or local government sector? This seems highly speculative or unlikely at best, so that the value of what has been done thus far would almost be written off in many areas.

Dr. SLAUGHTER. I share that concern with you. I have discussed this with people in the innovation groups over some period of time. I feel that it is going to be very important for NSF at some point in time to identify a process whereby it will be possible for the private sector, local and State governments to work with NSF in transferring and utilizing the developments of these innovation groups. We have not been able to do that at this point. I think that it is an area we are going to have to work on.

Mrs. HECKLER. Thank you. I have nothing more.

Mr. WALGREN. Mr. Brown.

Mr. BROWN. Let me thank both Dr. Slaughter and Dr. Branscomb for the presentations you have made. I think there are some hopeful signs in the reorganization, in the changes that are taking place there. Of course, we hope to capitalize on all of the hopeful signs possible.

With regard to the changes in engineering activities, I think the engineering community will look with favor upon the added emphasis given and the additional support that is reflected in the budget. That is all to the good.

The discussion over basic versus applied research which has been going on now for many years, is one that has always intrigued me. Very frankly, what I think bothered me more than anything else was the tendency that had occurred in some parts of the scientific or research community, and I guess it was primarily in the university community, to feel that there was some invidious distinction about basic research. It was sometimes even called by names such as "pure research," and as though there was something dirty about other kinds of research.

I feel that was a fruitless kind of thing and both of you have pointed out research has to be measured on the basis of contribution to human knowledge, not how far removed it is from application. I consider the reorganization regarding the support of applied research a positive step and, of course, I will be watching very closely to see the results.

Obviously, as you know, we are concerned about what is happening to some of the initiatives, such as Mrs. Heckler mentioned, and I want to ask you to verify the data which the subcommittee staff has supplied us.

According to our data, the current fiscal year plan calls for $5½ million for Intergovernmental Programs which funds groups like the New England Innovations Group. The expected revised fiscal year 1982 request zeroes it. Is that your understanding?

Dr. BRANSCOMB. I am not sure what information you have before you, Mr. Brown. As you are very aware, the final numbers will not be provided to the Congress from the administration until the 10th of March.

Mr. BROWN. I am not going to prejudge. The data we have is labeled "expected" and not "final". However, it shows zero for fiscal year 1982 for all elements of Intergovernmental Programs—that is, State science engineering and technology, State government programs, local government programs and Federal technology and information transfer activities and I presume that is the situation.

Well, obviously, there are going to be a lot of unhappy people over that.

Clarify for me the status of the new Division of Industrial Science and Technology Innovation, which contains many very good programs as you described in your statement.

Is that subsumed under the new engineering directorates or how does it fit into your plan?

Dr. SLAUGHTER. Mr. Brown, those programs are part of the directorate for scientific, technological and international affairs and are not subsumed under the directorate for engineering.

Mr. BROWN. They are, as I think, expected to be retained at approximately the present level or perhaps slightly under the present level, as far as you know?

Dr. SLAUGHTER. Yes. We believe that they will be supported below the present level.

Mr. BROWN. I have no further questions at this time, Mr. Chairman.

Mr. WALGREN. Any questions, Mr. Skeen?

Mr. SKEEN. No questions.

Mr. WALGREN. Mr. Ertel.

Mr. ERTEL. Thank you, Mr. Walgren.

I guess I am back where Mr. Brown was because I have been going through the material which was provided to us. With respect to the expected Reagan fiscal 1982 request and his 1981 plan, for the university/industry cooperative research projects program, the Reagan fiscal year 1982 request is expected to be half of what Carter's request for fiscal year 1982 was.

I guess I have got to ask you a hypothetical question, because we may not see you after the March 10 announcement.

When I see zero in some categories, it is obvious some people can't be back here to testify. What is your position with regard to those? Will they cripple the National Science Foundation if you assume these figures are correct, and will they cripple our effort in this country to start innovations and to really reindustrialize America?

Dr. SLAUGHTER. Mr. Ertel, we believe that those programs were sound programs. The proposals for support in the intergovernmental science area were for programs that in their own merit were significant and made a very positive contribution to the country's ability to move ahead in the areas we have discussed.

I support the priorities established in the overall budget that we are presenting to you because this is a clear indication of the principle role of support of basic and applied research in the core activities of the National Science Foundation. That is where the Foundation's strength lies. That is what is being presented to you as our first priority.

The specific numbers will be available after March 10. I hope that we will have an opportunity to appear before you again after that date and that you will be here to listen to us at that time so we can assess these numbers in some detail.

Mr. ERTEL. I will assure you I will be.

Mr. LANGENBERG. I might add some of the innovation programs we have had in the past, particularly some of the programs that had focused on interface between researchers in industry and in universities, programs which have focused on research and innovation in small businesses, will certainly go on.

I can't be specific about numbers at this time, but those, in our view, have been successful and have been important and have been valuable and you can expect that you will see them.

Mr. **Ertel**. I am not quite sure how it will be if you have a zero budget.

Mr. **Langenberg**. You are quite correct if the budget is zero on March 10, they won't be there. But I think you will see some of those programs.

Mr. **Walgren**. Dr. Branscomb.

Dr. **Branscomb**. I would like to supplement this important discussion with the following observation:

My somewhat limited experience in the executive branch taught me to make a careful distinction between policy and authorization and appropriation. Indeed, I was often on the poor end of that bargain where the Congress, with deep conviction that something was of great value to the country, passed a statute, authorized the work, and then, because funds were short, appropriated a little less than was needed to do a really good job.

Sometimes the people were not well-served by that mismatch. I think we should all be a little cautious at the moment. We should recognize that the administration has undertaken a revolution in policy with respect to Federal appropriations, and it may also have undertaken some very important changes in policy which govern the functions that it believes the Federal Govenment ought to pursue and those it should not pursue.

I think we should be cautious about reading into a budget message, particularly one that I have not read, and I don't believe any of us have read, and will not read until next week, the answers to the policy questions we are debating.

I think the appropriation document should be viewed as a challenge to policy formulation, and on your specific question of whether or not very substantial cuts in President Carter's proposed budget would jeopardize the revitalization of our economy, the answer to that has to be no, in the short term.

The real issue is, what do we do next year and the year after that?

So I believe we ought to focus very strong attention on the long-range policy content of what we do with limited resources. There, of course, the Congress has the ultimate job of deciding the answers and the administration has the responsibility to propose.

I hope the National Science Board will be included in the process of trying to define the issues for you and find some way to distinguish the programs that really work from the ones that were a good idea to try but do not have big leverage.

We will finally settle on a role for the Federal Government in science and technology that everybody can be enthusiastic about and will get the support that is required to do the job at a time when disposal of a part of the budget is very limited.

Mr. **Ertel**. I listened to your answer but I am somewhat confused. You said it would not be jeopardized in the short run and then talk about 1, 2 and 3 years. Do you refer to that as a long run?

Dr. **Branscomb**. Yes, sir.

Mr. **Ertel**. 1, 2 or 3 years is a long run?

Dr. **Branscomb**. Yes. I think in 2 or 3 years of the wrong policies we could see a noticeable deterioration of capability that would have economic consequences.

I do not believe it is true in 1 year, nor do I have any basis to believe today that any such long-term policy has been proposed by the administration. I just want to be very careful about reading more policy content into a budget document than I think represents the deep thinking behind it and the opportunity for the Congress and the administration to have a debate on that subject.

Mr. **Ertel**. I don't understand what you are saying, Doctor. I am not trying to be argumentative, but let me say to you if the budget document does not request funds and after the reconciliation process there are no funds, then certainly there is going to be an impact on policy in this country, because we implement policy in this country generally through utilization of money to effectuate it.

Now, it seems to me to argue the policy issue at the budget level makes sense, otherwise you are never going to have a chance to argue down the road. You may be arguing it with no chance to effectuate it.

Dr. **Branscomb**. I agree with that. Let me illustrate my point with one example. Although we are not here to discuss science education, that is clearly one of the issues.

Mr. **Ertel**. It certainly is one of the major issues.

Dr. **Branscomb**. Should there be a proposal to make a drastic change in the NSF's activities in the Directorate for Science and Engineering Education, I do not believe I can read a very clear philosophy of the Federal role in education from such a decision.

The reason for that is the central core of our policy at NSF is to fund research in educational institutions precisely because education is a central purpose of our investment. It is in the NSF Act of 1950, as amended. Indeed, section 3(a) of the statute reads: "The Foundation is authorized and directed to initiate and support basic scientific research and programs to strengthen scientific research potential and science education programs at all levels . . ." and so forth.

I submit that, if that policy is to be changed, there must be a change in the statute as well as a change in appropriations. I am sure that, if such a change were proposed, it would generate the appropriate debate.

I am only suggesting that it is always possible to consider adjustments in budgets in the context of a thorough debate of the issues. I just do not think we have heard all the arguments on that debate yet.

I am not suggesting it is wrong for the Committee to pay attention to the way the appropriations seem to express policy. Of course, you should.

Mr. **Ertel**. I guess I won't belabor the point, but I just don't agree with you. Quite frankly, even though a statute exists which sets a policy, the policy can be changed or even torpedoed, in effect, by the budget and appropriations process. It may still be the policy of the United States, but it is a hollow policy and it is there in name only without any ability to effectuate it.

I think it takes both levels. If you want to torpedo something, you can torpedo it and still leave it in name and go out and talk about it and have the rhetoric, but you don't have an effective policy.

What I am saying to you is that even though you can read what the policy is as set forth in a law, without the money to effectuate the policy it is an illusion.

Thank you, Mr. Chairman.

Mr. **Walgren**. Mr. Weber.

Mr. **Weber**. Thank you. I would like to ask a question that may be related to that indirectly. I am sorry I missed your testimony, but I understand you made references to the Japanese advancements.

As a new member of the panel, I have heard quite a bit about that before the subcommittee and the full committee. I am unable to get an answer and I hope you can explain. As long as you are talking about policy, what is the policy of the Japanese Government in its support of research and technological advancements? My frustration is in talking to other witnesses before other panels, I asked if they were able to explain specific projects and give examples. Can you explain the policy of that Government which seems to be so successful?

Dr. **Branscomb**. Perhaps in simple terms, I can try. I believe it is Japan's policy to base its economic survival on an internally competitive industry. Given the lack of domestic resources, Japan intends to do so on the basis of fierce internal competition, with very carefully modulated Government interference, with the Government primarily in a strategic planning role carried out in concert with leaders in industry and in the financial community, and with the Government also in a role to modulate very carefully what foreign enterprises are allowed to do in Japan. At the same time that they are attempting to husband their resources for the key industries on which they base their strength.

Second, another element of Japan's policy is to concentrate Government attention—and to the extent that they spend money and resources—on the industries that have the greatest potential to be successful, not those that are in the worst trouble.

Third, they focus on productivity and manufacturing, in other words, on competitive costs, believing that low cost is the key to market success.

And, fourth, they also will attempt to identify critical areas of supporting technology upon which the growth of strategic industries depend and in those areas make direct investments by either special tax treatment or in some cases actually spending money in direct grants to develop those supporting areas of technology.

Finally, it is important to appreciate that Japan's policy has clearly, until recently, been based on the acquisition of proven technology from other countries and its adaptation with improvements on a very rapid time scale in Japanese industry.

The Japanese now are reaching the point of parity and in some cases leadership technologically. Therefore, they are beginning to shift that policy toward rapidly accelerating advances in basic science, because they believe the leader has to lead in basic science and the follower can afford to borrow from others and play catch-up. They are in the transition of leader.

Mr. **Weber**. That indicates a much stronger planning and coordinating role of their Government than that of our Government. What about their recent role itself, does their Government directly envision a great deal more resources in this area of research than our Government does?

Dr. **Branscomb**. No. The percentage of GNP that the Government spends on R. & D. is lower than ours. However, it is very important to remember that Japan's defense expenditures are minimal, particularly in R. & D. So, on the civilian side, it is a bit more impressive.

But they target, or they have in the past targeted, their investments much more narrowly with almost an exclusively economic motive rather than a broadly distributed defense and social motive, which characterizes our priorities.

Mr. **Weber**. With the Government planning a corrdinating role, is it safe to say that also inspires a greater private investment in R. & D. than in this country?

Dr. **Branscomb**. Certainly it is true in the strategic industries, because the way the Japanese Government tends to support strategic industries is through the National Bank of Japan. The strategic industries know they are strategic; everybody in Japan knows it, and they all behave accordingly. However, the Government allows those industries to compete vigorously with one another and does allow them to fail.

Mr. **Weber**. Thank you.

Mr. **Walgren**. Mrs. Heckler.

Mrs. **Heckler**. Dr. Branscomb, I would like to ask you to clarify a point for me obviously in the wake of budgetary cutbacks we are dealing with in balancing the equities in the NSF budget and other budgets. In that regard, dealing with the current productivity emphasis of the United States, which is very slowly coming and long overdue, there is an obvious need for funding at least in the engineering field. The need seems to be acknowledged by the establishment of a separate Directorate of Engineering.

In this context of budget cuts and need to increase productivity we are recognizing that the engineering area—at least I think—the engineering area must be supported.

I also am left with the strong impression that somehow we have failed to see the dimensions of our engineering needs for some time and that we are playing catchup in an almost meaningless sense because we don't know the dimensions or the time necessary to meet this challenge. Is this a correct perception, and if so, why has it happened?

Dr. **Branscomb**. I think it is a correct perception on your part. My personal opinion is the explanation has several origins. First, as a scientist I will say frankly that I think we scientists allowed the country to interpret the achievements of the 1960's as scientific triumphs, when most of those pictures on this wall were carried out by engineers.[1]

No. 2, we developed a cult of interest in the scientific research and development as the singular important thing in industry. In fact, manufacturing is a very demanding technical art. The Japanese revere manufacturing engineers. In this country if you were to make a poll of engineering undergraduates and ask them whether they envision going into a career in research and development or a career in manufacturing, the response would be 99 to 1 for research and development. It would not be so in Japan.

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[1] Photographs of Appolo mission program activities.

We seemed to get data that convinced us, as a people, we were overproducing engineers in the sixties, because of the shift in Federal investments in R. & D. in the waning years of the Vietnam war away from defense strategic R. & D. Defense money went to weapons procurement and operations, which reduced the surplus of engineers in the aerospace industry. This was followed by a recession in the commercial sector between 1972 and 1975, out of which we came rather slowly, so we had for a long period of time there with a surplus of aeronautical engineers and some other categories, a slack demand from the private sector, and a gradual period of recovery.

We have now arrived at a time when the private sector, at least for key engineering skills, is desperately competing for the available people, to the point we are now raiding the faculties and thereby "eating up the corn seed," as the expression goes. I still think we have not appreciated the importance of engineering in a production environment as an exciting career and an important orientation for young engineers.

So part of it is a temporary lapse in our culture, if I can put it that way. We think of the factory in terms of Charley Chaplin's caricature of the bad features of industrial life in the Depression, as a source of pollution rather than a source of technical excitement and enterprises.

Mrs. HECKLER. Obviously, this is changing with the proposals and, I think, congressional support for such things as accelerated depreciation. That is going to show the challenge of new technology as being a very exciting one, no doubt.

Do you ever see a situation where we will get back from the boom to bust which we have gone to? This boom to bust in engineering I think has produced part of the slackening of interest in universities and so forth. We are now at a different point of the circle and we are at the boom again, and as you say, the raiding is going on and we should be aware of it. Can you see the negative contour returning?

Dr. BRANSCOMB. Yes, I can, because I do not see any way to avoid engineering, or for that matter scientific employment being tied to the economic cycles; and until the economists or someone can figure out how to smooth out the economy as a whole, we will have those cycles.

However, I agree with Guy Stever's observation before this committee a few days ago that we probably do not have a numerical problem with people who have been labeled "science engineers," with a few exceptions over the long term.

One may think of that technical community as kind of a pyramid with very highly skilled scarce people near the top of the pyramid in relatively small numbers and down at the bottom of the pyramid very valuable, useful people engaged in activities which are typically not at the cutting edge of technology and very often involved in some administrative, managerial, or supervisory aspect. We need to keep our technical community as career flexible as possible, so that when the swings in the economy and demand for engineering come, instead of throwing people out of work they use a flywheel of shifting people in and out of R. & D. as the principal use of their talent. It is not an easy problem, and I am not very optimistic that the Federal Government can in fact carry out a very useful balance-wheel strategy, when a simple answer to your question would be to let us pay attention to major national engineering projects when we are in that slack time in order to keep pressing the capabilities ahead. That is a good policy, if we had the nerve to back away from them in times when the skills are in short supply.

I expect our record in doing that is not very good.

Mrs. **Heckler**. A great deal of it depends on the expanse of our international market and our ability to meet foreign competition and reach our potential.

Thank you.

Dr. **Langenberg**. I might add, Mrs. Heckler, I think another factor is unique which did contribute to the depth of the last bottom in the cycle of public interest, student interest in engineering and technology. We have had this at least as early as the sixties and seventies when technology itself and technologists in general became somewhat unpopular among parts of the population and in particular among students then in college.

I think that added to the economic circumstances at the time, caused the number of students that went into engineering to decrease very sharply. As you know, it has in recent years been increasing very sharply.

Whether or not those attitudinal effects will again, at some later time, coincide with an economic downturn to produce another large oscillation, I think it is difficult to say, but I think it was a phenomenon in the last dip.

Mrs. **Heckler**. Hopefully one that will not be repeated.

Dr. **Langenberg**. Yes. Thank you.

Mr. **Walgren**. Thank you, Mrs. Heckler.

We anticipate that even though you retitle a directorate as engineering alone, programs that would have directly benefited engineering development will be cut, particularly as I understand it some which would have provided instrumentation. And some programs that would have supported fellowship trainees which were originally under the science education directorate, will no longer be funded. Is that correct?

Dr. **Slaughter**. There were some special programs that represented new starts for fiscal year 1982, Mr. Chairman, that will not be funded as new initiatives. Some of those things that we believe are important programs can be funded through our core research support programs. Even though we may have to make some changes in the ways in which we anticipated supporting programs for instrumentation, for example, we believe that we will be able to conduct some of those efforts through our core research.

Mr. **Walgren**. Will instructional implementation be, in your judgment, one of those that will be carried on through the core support system?

Dr. **Slaughter**. The instructional equipment is less likely than the research equipment. But, again, Mr. Chairman, I would argue that to a large extent this will evolve from the view of the community and advisers to our Engineering Directorate from the disciplines that are concerned. What they believe the most important areas that should be supported will fall out.

Mr. WALGREN. Those are the areas that would have particularly supported undergraduate education which, is as I understand it, where the problem is.

Aren't we subject to the criticism that although we are willing to make new starts in changing the titles on paper, we are not willing to make new starts and in fact are retreating in areas that are very important, especially given the broad consensus that there is a crisis here and that it is the kind of thing that even the administration, in its call for new investment, would be supporting?

That leads me to what I wanted to explore with you. That is, where do the administration's budget numbers come from? What kind of input has the National Science Foundation had in determining these numbers?

Sitting here listening, I get the feeling that you really are, through no fault of your own, put in a position only to react to numbers being presented from the outside or from some place other than within NSF. Is that true?

Dr. SLAUGHTER. That is not exactly true, Mr. Chairman. The administration is facing clearly a very critical set of issues concerning economic revitalization. We are in fact, like many governmental agencies, faced with making some changes to our earlier budgetary proposal. We support these changes. We support the position that will be brought forward to you on March 10.

We believe that the administration has in fact insured strong support for the sciences and engineering which are the core of the National Science Foundation budget.

The proposals that will be brought to you on March 10 result from the administration's examination of the initiatives that they felt were important and its economic recovery program. The National Science Foundation, like many other agencies, was informed of the administration's general guidelines.

To the extent possible, we argued for strong support of our core research program. That is what is being reflected in what will be brought to you next week.

Mr. WALGREN. When you say you argued for strong support of your core program, that means that you were at least willing to support the reductions in these other areas.

Now, my question is, Where is the independence of the Science Foundation? You are appointed for a 6-year term, is that correct?

Dr. SLAUGHTER. Yes, sir.

Mr. WALGREN. You are not subject to dismissal during those 6 years, is that correct?

Dr. SLAUGHTER. I serve at the pleasure of the President.

Mr. WALGREN. I see. So you could be interrupted in midterm? Let me turn to Dr. Branscomb. [Laughter.]

Dr. BRANSCOMB. I, sir, am invulnerable. I suppose I could be impeached. But yes, sir, I have been appointed too as a member of the Board for 6 years, and I have been elected by my colleagues as chairman for 2 years.

Mr. WALGREN. You indicated that before the day was done the National Science Board would be in the middle of this, if those were your words. My reaction to hearing this is that the Science

Board is not yet in the middle of it. Congress tried to set up some kind of independent national board in the science area because it did not feel science is political. If this process becomes subject to some kind of overall political philosophy, then we will sacrifice a great deal of achievements that science can make to our society.

When will the National Science Board make some specific recommendations of its own in this area?

I wanted to underscore what Mr. Ertel was driving at; that is, without the authorization, there is no way that any later funds, as I understand it, can be moved into these areas, no matter what the later view of the National Science Foundation Executive Board is, and we are ultimately thinking that authorization might be hostage to the national political move until independent voices raise themselves to establish the validity of these priorities.

Dr. **Branscomb**. Your question, which, of course, is one I am concerned with, helps me clarify my exchanges with Mr. Ertel which got me off my point. I do not think I expressed myself well.

It is true the National Science Board was not asked by the administration to tell it how we would deal with a budget at a different level than the one President Carter sent forward.

It is a perfectly reasonable question, because I am not at all surprised the administration is going to try to save some money out of our budget. I think it is appropriate that we join in that effort and see what money can be saved.

I observed that the budget process, if one looks only at line items that appear before this committee and it says how much money is in each line item, they do not in all cases absolutely define all of the totality of the work of a given character in the Foundation.

If one deals in one way with a line item called science and engineering education and one deals in another way with a line item called mathematical and physical sciences research, which includes within it student assistanceships, then I claim I have not been given a very clear signal of the administration's philosophy with respect to the support of students in graduate and, postgraduate institutions.

I have been given a very clear message that the President feels he needs to reduce expenditures, with which I concur. So I only make the observation that I think there should be careful scrutiny by this committee of the substantive content of what we should be doing independent of the budget line category within which we have in the past funded that activity. And even if there are no resources that the administration is at least prepared to request, or can afford, for a given activity at a given time, we should still debate the question of whether or not we should seek those in the following year.

We should try to engage everybody in this process in the Congress and in the administration. I believe that a lot of that discussion is still to be had. That is all I meant to say.

I absolutely agree with you, Mr. Ertel, that the final determination by the Congress signed by the President of a budget action determines what is going to happen, because what is funded happens and what is not funded does not happen.

Mr. **Ertel**. Will the chairman yield?

Mr. **Walgren**. Yes.

Mr. **Ertel**. I am sorry to get back to this, but some of the things you said concern me. I don't really think Dr. Slaughter meant some of the things he said, but I am puzzled by the attitude. The attitude bothers me.

You say if we cut out a line item for a direct program, we are going to move into another directorate another line item, basically the same function, and we will call it something different. I wonder if that is really something we want to foster?

Dr. **Branscomb**. Excuse me, I did not mean to say we would do that.

Mr. **Ertel**. You implied that.

Dr. **Branscomb**. What I said is there is already activity going on. I cannot deduce from just a budget item without a statement of policy that goes with it what the intent of that budget reduction is.

What I can tell the Committee is that, if the Science Foundation's budget is x rather than y and x is smaller than y, we are going to invest less in trying to move the country ahead in science and technology than we would otherwise have done. Also, the distribution of how that money is allocated across our programs is an appropriate subject for the committee to debate and, once the budget is public and ready to defend, and discuss, for the National Science Board to express its view on it.

We cannot express a view of the National Science Board on a budget that is privileged and that we have not seen.

Mr. **Ertel**. You mean you have not had any input into the budget process at all, you have no idea what is coming out of the budget?

Dr. **Branscomb**. I have been kept informed of the progress, but I am not a direct part of that process. There is no time to do that on a 2- or 3-week basis with the National Science Board.

Mr. **Ertel**. In other words, what we are getting is a budget drawn up by a political entity, OMB, without input from the Science Board whatsoever and if they decide to cut out a directorate, they have not asked your advice on it?

Dr. **Branscomb**. The National Science Foundation was obviously consulted. The Director had full opportunity to discuss with people in OMB the character of what was being done.

Mr. **Ertel**. I think we should ask the Director what he did.

Dr. **Slaughter**. I met with officials of the Office of Management and Budget and discussed the proposals that are embodied in the budget that will be coming to you on March 10. The process did not include a detailed review by the National Science Board. The process was one that was done very quickly when the administration determined that some rather major changes needed to be taken in order to meet important budgetary restrictions.

Mrs. **Heckler**. Will the gentleman yield?

Mr. **Ertel**. I don't have any time left, but will be happy to yield.

Mrs. **Heckler**. I would like to have some fun. My point is: "Ever was it thus." This is not new. What is new is the variety of the cuts and variety of changes. The policy has always been along these lines. I think two things are new.

One is the dimension, the proportions, the ratio, that is a matter of staggering significance. There is, of course, a 14-percent inflation rate that is also staggering and that perhaps has caused the action and reaction.

The second point that is new, and this I think is a very thinkable point, is the attention of the public to the process. Suddenly, this is a public thing rather than a secret thing, which only a few members of the committee are aware of at different times.

I, for one, having watched this in other areas, frankly feel budgetary restraints of every administration are apparent, whether it is through a single process or intervention of OMB without the statement of any appointed official or any official who serves at the wishes of the President. The fine hand of the decisionmakers always presided at OMB and certainly in the last administration and now you have some kind of consultative process, but I don't think that there is a very severe departure from what I have heard in the past.

Mr. **Ertel**. Will you yield back?

Mrs. **Heckler**. Absolutely.

Mr. **Ertel**. I think what you said is that is the way it has always been and that is the way it is going to be now.

Mrs. **Heckler**. No, I didn't.

Mr. **Ertel**. I would say to you if we make a mistake, we don't have to make it in the future. If I am going to change a policy and make a very dramatic change in policy, I don't think I am going to have a financial expert make a change in the scientific field without finding out what the implications of that change are by talking to the people in the field. It seems to me that although you may not agree with the people you talk to, and you may reject their opinions, at least you ought to have their opinions. You ought to have that input because we have no idea what we are doing.

It seems to me that is the proper way to start. I would think most management people in the country would say if one wants to invest, he finds out what the implications are and makes a decision rather than making a decision and then saying "Here it is, fellows." That is what I am hearing here. They are saying: Gentlemen, here is the decision.

Mrs. **Heckler**. If I might just add a comment.

Mr. **Ertel**. I am happy to yield back.

Mrs. **Heckler**. I feel the point I made was in response to your element of surprise, because it is not a surprise. I do not suggest that the process should be included.

I think, from their own statements the process thus far has involved some consultation with the Director of NSF and it would be impossible, as he said, to engage everyone in every Board throughout the Government. Ultimately "The President proposes and Congress disposes," and the process is only a natural and continuing one. I say that is why this consultation in our situation here is so very important.

Mr. **Walgren**. Thank you very much. I feel that one of the things I see as relatively unique in this circumstance is the time frame in which the issue will be resolved and that because of the nature of the budget process I wonder whether we are going to have a very long time to discuss this. I get the reaction or the feeling from Dr. Branscomb in a sense you are willing to almost, as we say in Pittsburgh, wait until next year. [Laughter.]

Mr. **Walgren**. Well, it seems to me that is exactly what we have been doing in Pittsburgh for an awfully long time and it is always a very dissatisfying season.

My question is, when can we expect some guidance from this independent Board that Congress has set up that would give some support for whatever the view of the science community is about the priority of the programs that administration proposes to eliminate?

Dr. **Branscomb**. I think the Board clearly cannot do that prior to the budget actually being established and submitted to the Congress.

So next Tuesday is the earliest possible date. Subsequent to that date, I believe you can, to the extent I can get a consensus out of the Board, as we have to meet in order to answer any specific question we have not already discussed, but I believe we can get answers for you and I think I can anticipate the answer.

Let me just do that. First of all, I think we will want to express the view that the total budget of the Foundation is an important matter, that we appreciate the need for constraint, and that we think the Appropriations Committees in particular, and certainly this committee as well, should seek to make the right strategic balance of science and technology investments across the Government.

There should be an S. & T. look at the whole budget, and that means you should look at what has happened in other agencies which might be more deleterious or less to some particular scientific capability.

One should also look at defense R. & D., partly from a positive point of view to see the support they may be able to provide to the same university community we are helping. That would help.

I would also hope the administration will finish its staffing so it, too, can look at an S. & T. crosscut across the Government on a functional basis and better understand the balance that is there in the R. & D. function with respect to national objectives.

It is possible that, if the key jobs were filled that normally have the responsibility to make that crosscut, some different judgments would emerge.

It is possible those different judgments might emerge in the course of the spring when the Congress is wrestling with its budget. I do not know.

All I meant by the earlier argument is to say the total numbers in the budget are very real. If this committee does not authorize us to do certain activities, we will not be able to do them even if we have the money.

Beyond that, I think the National Science Board, and here I back up the Director, I think the Board will tell you if the bottom line comes out that we have to take a serious reduction in what might have been our budget, recognizing it is not that much of a serious reduction over last year in current dollars.

We would undoubtedly put our highest priority on the core scientific research, largely in an academic environment, thereby having educational value. But we would also attach important value to some relatively small activities which may be points of controversy.

Those relatively small activities can be very important. There are some activities in which in the past we have attempted to have substantial programs which perhaps we cannot afford them any more, but where a small activity would still express the Federal leadership that can catalyze local, industrial, or State level activity that would help mitigate at least the budget stringency that is involved.

But the basic, and from a very broad point of view, the basic priorities that I think the administration expressed when they had to deal with this budget, given that a reduction is necessary, were in accord with the Board's views.

Mr. WALGREN. I guess it bothers me when you say "If we have to take a reduction of a certain magnitude." In my view, the unique structure of both the Science Foundation and particularly the Board is its independence and its ability to express a view prior to having to take that cut. What bothers me is that we have the Commerce Department inside the administration, because we want them to take the cut, but we have you outside the administration, because we want to get your view prior to that question being imposed on you or the answer to that question being imposed.

Dr. BRANSCOMB. Yes; the National Science Board and the Director constitute the Foundation and we are part of the administration. We cannot send a budget request to you that does not go through OMB and as part of the President's budget.

What the Board can do is express its views on the importance of various fields of science and science education and the other activities that we are engaged in.

We also participate in great depth and detail with the Director and his staff in the formulation of the Foundation's own proposals to the administration.

Indeed in the normal budget process we are very deeply involved in reacting back to any President's instructions to reduce the total level of the budget.

We are at a unique point in time which occurs once, well, occasionally at 4-year intervals, in a process that has taken an entire year and in which the Board has been very, very deeply involved in construction of a budget. It was done in one context, and we are now in a different political context. We have no time to do a year's work in a week.

Mr. WALGREN. You indicated that you would anticipate the Board's reaction in your comments. Is the Board empowered to give this committee directly its detailed reactions to the budget proposals of the administration?

Dr. BRANSCOMB. Certainly all of the Board members can give you their opinions.

Mr. WALGREN. How about the Board?

Dr. BRANSCOMB. Whether or not, from a formal Government's point of view, I would have to ask Mr. Herz or somebody to give me a legal interpretation on the boundary line between our responding to your proper request to us for our views on American science and technology and our views on the Foundation's policy versus giving you a specific budgetary commentary which comes under a different set of statutory restraints.

Mr. **Walgren**. I gather I can't get what I am interested in. My point is, unless there is some kind of creditable view that some of these cuts are not proper, we are all going to wait until next year and you will zero out these functions because the Congress is largely in a mood to cut. You will zero out these functions and then perhaps at some future date you will start again, but you will lose whatever you lose from what you had last year.

Dr. **Branscomb**. You can get the views of the Board and individual Board members' views on the substance associated with every one of the program activities that will be dealt with in a document that I will see for the first time next Monday in its final form, or Tuesday whenever it is. I think we have to wait until that budget is before you before you can expect us to answer those questions.

Mr. **Walgren**. Let me say I am one member who will be very interested in the Board's, as a specific body's, view. We are all under time pressure.

Dr. **Branscomb**. Mr. Chairman, I have a time constraint, I have a problem with an airplane in getting to New York, if you are nearly done with me.

Mr. **Walgren**. I am sorry to have gone on at such length and I apologize for that.

I want to thank you and the rest of the panel from the Science Foundation. I appreciate your coming to Washington especially for this.

Dr. **Branscomb**. Thank you, sir.

Mr. **Walgren**. And I understand, you will be joining us again on Tuesday of next week, Dr. Slaughter.

Dr. **Slaughter**. Yes.

Mr. **Walgren**. Thank you very much.

The next panel includes Robert Frosch, president of the American Association of Engineering Societies. Dr. Frosch was former Administrator of NASA under a previous administration.

Joining him will be H. W. Paxton, vice president for research and development of the United States Steel Corporation. Mr. Paxton is here representing the Industrial Research Institute.

Welcome to the committee. We appreciate your coming and your patience in waiting for us to finish our session with the first panel.

I will ask Dr. Frosch to proceed first.

STATEMENT OF DR. ROBERT A. FROSCH, PRESIDENT, AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES

Dr. **Frosch**. Mr. Chairman, members of the committee: My name is Robert A. Frosch. I am president of the American Association of Engineering Societies, which brings together, in a federated way, 38 U.S. engineering societies for the purpose of education and the analysis of public issues—issues facing the country relevant to engineering, and issues facing engineers in their role as citizens working for the public good.

I would like briefly to touch upon several subjects. First, let me note that we face what can only be described as a developing crisis in American engineering education. This crisis arises, paradoxically, from the high rate of employment of new bachelors'degree engineers in industry. The demand for engineers at this level, at the present time, is so great that nearly all graduates can find immediate employment.

May I say, Mr. Chairman, I have a prepared statement which I have offered to the committee for the record, and I would propose to summarize excerpts from it.

Mr. **Walgren**. Without objection it will be made part of the record and we appreciate your summarizing it.

Dr. **Frosch**. I offer some statistics in my prepared statement. The key point is that the salaries that are being offered to bachelor degree engineers have reached the point where they are more than competitive with the possible advantages of going on to graduate school, at least in the view of the young engineers who cannot see the period in time when the salary, forgone while going to graduate school will be made up.

The consequence of this situation of success in engineering is a situation in which the number of American students going on to graduate work in engineering has been decreasing steadily over the past decade.

In addition, as Dr. Branscomb pointed out, the lure of industrial salaries has begun to take faculty members away from engineering schools.

As a result of these two kinds of factors, the ratio of faculty to students has markedly decreased, so there are many more students per faculty member in the graduate schools at the present time. We are beginning to be concerned about the result of this changing ratio on the quality of engineering education.

The quality of undergraduate students is very high.There is some concern that the quality of graduate students, while good, is not as high as the quality of undergraduate students.

I think these are some of the factors behind what Dr. Branscomb referred to as "eating the seed corn": that is to say, we are using so many engineers in industry now that we are concerned about the health of the educational machinery that produces those engineers and about the economic factors that are producing that situation. We have a concern for our ability to supply our needs in engineers, if the requirement continues as it is.

These factors are made worse by the difficulties in keeping up with instructional equipment, that is, the equipment which is used in the education of undergraduate engineers, thus in addition to the faculty-student ratio problem there is an instructional equipment problem, and the schools are extremely concerned about that as it may affect future quality.

This adds up to a concern about the ability to produce enough graduate school engineers, and keep enough faculty, and keep enough instructional equipment to have a healthy engineering education system.

Now, the consequence of this would appear to be that since engineering is the basis on which our industrial productivity is based, that as we begin to run out of a capability to produce engineers at the rate we require them, we will run out of the ability to have enough engineers to improve productivity, improve design and compete with better products.

With regard to the international competition, the education of engineers continues to be an apparent high priority in both Japan and Western Europe and I am informed that at the present time Japan is graduating annually more engineers than we are with a markedly smaller population. That accounts for the ratio statistics that Dr. Branscomb gave.

What is required is some way of producing a better incentive for some engineers to continue into graduate school so that we have a supply of graduate trained engineers. These are required for industrial research and development, and because a number of engineers with that kind of graduate training are required to staff the university faculties.

We need some means of improving incentives both for graduate schools and for career university teachers and research workers. There is a differential in salaries between university faculties and industry and this presumably has some effect on the ability of industry to hire faculty members away.

There are additional disincentives with regard to both graduate school recruitment and the retention of faculty, as well as the difficulty of maintaining adequate research equipment in the universities.

I referred earlier to instructional equipment used for undergraduate students. I refer now to research equipment which is used both for the graduate work and for the research that both graduate students and faculty do to keep themselves up in the state of the art, and to contribute to basic engineering knowledge which in turn feeds into the innovative process.

Now, all of this situation that I have described, particularly the part about the lure of industry to undergraduate engineers, is somewhat different for engineers than it is for scientists.

There are excellent careers for bachelor's degree engineers in industry, but there are few careers for bachelor's degree scientists in industry, and the bulk of scientists are not employed in industry, so the feedback of graduate scientists to industry has a different character than feedback of engineers. We have a more acute problem in keeping the engineering schools operations going than we do in the science school operation at the university level.

Both engineering and science, I would interject, are having considerable difficulties in the secondary school and elementary school area.

Now, it is possible, as we have done before, that these difficulties can be improved by an infusion of Government assistance, but the amount required appears to be very large. In fact, the estimates made by engineering school deans of the national requirement for instructional research equipment over the next decade varies between $1 billion and $2 billion, so the amount of investment appears to be closer to one or $200 million a year than to any budget numbers that have appeared, to my knowledge, in anybody's budget for instructional and research equipment.

That does not deal with the requirements for the other problem; namely, comparability in graduate faculties' salaries nor incentives for students to forego the difference in salary that they would make by going into industry immediately, so that they stay in graduate school.

It is the case that eventually an engineer with a master's or doctor's degree makes a higher salary and very possibly a higher lifetime income than an engineer with a bachelor's degree, but it takes a long enough time to catch up that it is usually not within the obvious economic computations of a 21- to 23-year old bachelor's degree engineer.

Whatever actions are taken by the Government to assist in solving these problems directly, it appears that an important role could be played by NSF as well as by the agencies supporting mission-oriented research. This role would be to provide incentives and to catalyze arrangements between universities, Government and industry that would provide industrial support to improve some of the situations.

I have in mind the possibility not only of industrial funding to assist engineering schools, but the provision of equipment, the use of industrial equipment for teaching and research purposes, and the interchange of students and faculty with industrial engineers and research people.

These activities might be in the form of students and faculty doing work in industry, particularly graduate students and graduate faculty who might provide useful innovative ideas; both would benefit from the contact. Some such programs exist. I think they could be systematically expanded.

I also have in mind increased use of experienced industrial people as part-time faculty at universities. This would have two important effects.

It would supplement availability of experienced engineers as teachers, and strengthen a useful flavor of industrial realism in the engineering education curricula. I think it might be worth exploration of the possibility of a private foundation to channel industrial and private funds to the support of engineering education; NSF might play a useful role of cooperation in such an initiative.

It would appear that NSF could have a useful role to play in helping to attack these problems.

It is also clear that amounts for these purposes in the NSF budget are quite inadequate to solve them.

Therefore, whatever amounts are finally authorized and appropriated, there will additionally be a role for NSF and the mission agencies to provide services to encourage other arrangements to help solve these problems.

I noted earlier that engineering and the process of developing technology and transferring the results of science into technology is what creates industrial-agricultural productivity, and creates the goods and services that enable us nationally to compete. In fact, this kind of technological innovation has traditionally been the fundamental trigger and support to U.S. economic prosperity.

There is considerable evidence that in some fields and portions of industry innovative and productive capabilities have slackened, particularly in comparison with some of our foreign commercial competitors.

We need some means by which industries that have ceased to be as innovative as they might be can be helped to regain their competitive force. Some means for providing a stimulus of this kind seems to be needed.

It is not clear that the workings of the marketplace, which tend to be short term, will do this.

NSF may also have a role in this area by providing catalytic support of research which might be cooperative between industries seeking innovative help and university graduate research in education which can assist in providing it.

The combination of university research interests coupled with the practical requirements of industry seeking new products and new ideas is likely to be healthy for both, but it appears that some kind of marriage broker is required in many cases.

This seems a sensible and not overly expensive Governmental role; namely, stimulating a longer-range view than it is easier for markets to take, and provide for stimulation with broad technology transfer and use.

The bulk of the engineering research that is supported by the Government is that supported by the mission agencies, DOD, NASA, Department of Transportation, and so on. The role of NSF is to examine the fields of research supported in this manner and do those things that are required to round out the field of research in areas that make sense for technological and ultimate commercial development, but are not covered by immediate mission requirements, or are not otherwise immediately stimulated by industrial requirements.

The philosophy I am suggesting is simply that there is a public interest in caring for the long-range future of engineering innovation in a way in which short-term market forces do not do. This is the role of stimulation. From this point of view we welcome the reorganization of the National Science Foundation because it will provide a focus on engineering, a focus which will enable it to examine the subject in a cross disciplinary manner, looking across engineering, and in a way which looks at engineering from a point of view of national requirements and industry requirements.

The National Science Foundation can well accomplish the same ends proposed for a national technology foundation, provided the results of the reorganization are carried out vigorously and that there is sufficient budgetary support really to do the task.

We look forward to assisting the NSF in carrying out these purposes in any useful way that the engineering societies can.

Before concluding, I would like to make one further point, which has really been referred to in the previous discussion, but is not necessarily connected with NSF authorization.

The type of national problem being discussed here today is basic for our economic life and along with similar problems of engineering, science and technology will need to be addressed at the national and Presidential level.

The AAES and its societies believe it is important for the President to fill the post of Science Adviser and Director of the Office of Science and Technology Policy. The President needs to have direct unbiased technical advice on technical problems immediately available to him. This is not a matter of the scientific and engineering community's access to him. It is a matter of his easy access to them, and what they know and do, and he can best get this through an adviser on his staff.

Thank you, Mr. Chairman, for the opportunity to put forward our views. I will be happy to try to answer the committee's questions.

[The prepared statement of Dr. Frosch follows:]

TESTIMONY OF:

Dr. Robert A. Frosch

President

American Association of Engineering Societies

Before the

House Committee on Science and Technology

SubCommittee on Science, Research & Technology

5 March 1981

Mr. Chairman, Members of the Committee: My name is Robert A. Frosch. I am President of the American Association of Engineering Societies, which brings together, in a federated way, 38 U.S. engineering societies for the purpose of education and the analysis of public issues, issues facing the country relevant to engineering, and issues facing engineers in their role as citizens working for the public good. It is a pleasure to appear before you today at the invitation of the committee, to discuss the subject of American engineering and its relationship to the National Science Foundation.

I would like briefly to touch upon several subjects. First, let me note that we face what can only be described as a developing crisis in American engineering education. This crisis arises, paradoxically, from the high rate of employment of new bachelors' degree engineers in industry. The demand for engineers at this level, at the present time, is so great that nearly all graduates can find immediate employment. In its November 1980 Bulletin, the Engineering Manpower Commission reported that 5% of new engineering bachelors' degree recepients had no offers or plans, while the corresponding figure for those with new MS or PhD degrees was only 2%.

The salaries that are being offered have increased markedly over the past several years and have become more than competitive with the possible advantages of increased salary for the first 10 years after attainment of a graduate degree in engineering. The December 1980 Bulletin of the Engineering Manpower Commission provides the data for the following computation: A 1980 graduate with a BS degree in engineering who chose to go to graduate school for four years, instead of starting an industrial job at the median salary (½ would make more, half less) for a new bachelor in engineering, would require 8½ years at median PhD starting salary to make back the total salary lost in the four years spent in graduate school when he or she might have been employed. Thus, it takes a total of 12½ years to break even, not counting the first four years of raises as a working engineer with a bachelors' degree. A consequence of this disparity is that the number of American students in PhD degree programs has decreased over the past decade, while the number of foreign students in PhD programs has remained about steady. However, most of these foreign students return to their home countries and do not increase the number of graduate U.S. engineers to a great degree.

The lure of industrial salaries has also taken some faculty members away from engineering schools. As a result, the ratio of faculty to students has markedly decreased in the past few years. This has caused concern about the resulting effect on the quality of engineering education. At the same time, the deans of engineering schools note that the quality of undergraduate students is probably the highest that it has ever been, and they are turning away candidates. While the quality of students in graduate schools of engineering is good, it is not as high as that in the undergraduate schools, when measured on a percentile class rank basis.

It appears that the consequence of these forces will be a severe shortage of graduate degreed engineers and, consequently, a shortage of engineers with the kind of background and training that will make them suitable candidates for faculty positions. Thus, we face a continuing drain on faculties and, therefore, on the capability of the engineering education system to continue to turn out either undergraduate or graduate degreed engineers. Thus, we face the possibility that the very forces that are increasing the demand for bachelors degree engineers are simultaneously destroying the system that provides a contininuing and increasing flow of engineers.

At the same time, the instructional equipment in the engineering schools has been aging, and the replacement rate has been less than that necessary to keep the capability for laboratory and practical instruction up to date. If not corrected, this situtation will strike at the continuing quality of American engineering education.

It appears that this problem, if not successfully addressed in the next several years, may lead to a considerable difficulty in supplying engineers at the rate at which they are currently required by the country. Since engineering is the basis for industrial productivity it would appear that this tendency, if unchecked, might strike at our attempt to improve our economy through improved productivity, better design, and better products. This worry is accentuated by the fact that the education of engineers appears to be a high priority both in Japan and Western Europe; at the present time, I understand that Japan graduates more bachelors' degree engineers annually than the U.S.

What is required is an immediate incentive for some engineers to continue into graduate school. There are two reasons for this, one because we need some number of graduate trained engineers for industry for research and development, and two because we need a number of engineers to staff university faculties. Some means of improving the incentive both for graduate school and for careers as university teachers and research workers is important.

A differential in salaries between university faculties and industry provides some economic disincentive to engineering faculty employment. A comparison of data in the 1980 publication of the Engineering Manpower Commission: Professional Income of Engineers (pp 20, 76) suggests that on a 12 month normalized basis, the highest paid (upper 10%) university faculty do as well as the highest paid (upper 10%) national average PhD. The median university faculty member earns about $3000/year less than the median PhD engineer in the country, while the lowest 10% of the faculty earn more than $4000/year less than the lowest paid 10% of PhD's on a national average basis.

An additional disincentive in the faculty retention problem has been the increasing difficutly of maintaining adequate research equipment in the universities. I referred earlier to instructional equipment, where the problem is providing equipment which will give students experience which is really comparable to the type of equipment and engineering experience they will face in industry. I now refer to the equipment which is used in engineering research in universities. That is the research which not only trains the graduate engineers for more advanced work, but that equipment which is used to do the research work that provides new basic engineering knowledge.

I should note that these industry/education economic forces are different for engineers than for scientists, since there are generally few industrial or other scientific careers for scientists with bachelors' degrees only. Indeed, I believe the bulk of scientists are not employed in industry, but in universities, research institutes and government.

It is possible, as in previous periods in our history, that these difficulties can be improved by an infusion of government assistance, but the amount required appears to be very large. The estimates that have been made by engineering school deans vary between one and two billion dollars in instructional and research equipment over the next decade. This does not include the requirements for some means of making graduate faculty salaries more comparable with industry salaries, nor does it deal with the problem of incentives for students to remain in graduate school while they give up considerable immediate income that could be earned if they went into industry immediately upon earning their bachelor degrees.

Whatever actions are taken by the government to assist in solving these problems directly, it appears that an important role could be played by NSF as well as by the agencies supporting mission oriented research. This role would be to provide incentives and to catalyze arrangements between universities, government and industry that would provide industrial support to improve some of these situations. I have in mind the possibility not only of industrial funding to assist engineering schools, but the provision of equipment, the use of industrial equipment for teaching and research purposes, and the interchange of students and faculty with industrial engineers and research people. These activities might be in the form of students and faculty doing work in industry, particularly graduate students and graduate faculty who might provide useful innovative ideas in industry, and benefit from the contact both economically and educationally. Some such programs exist; they could be systematically expanded.

I also have in mind increased use of experienced industrial people as part-time faculty in universities. This latter idea would have two important effects: it would supplement the availability of experienced engineers as teachers for both undergraduate and graduate students, and it would strengthen a useful flavor of industrial realism in the engineering education curricula.

An additional idea worth exploration would be the establishment of a private eleemosynary foundation to channel industrial and private funds to support engineering education. NSF could usefully cooperate with such an initiative.

It would appear that the NSF could have a useful role to play in helping to attack these problems. It is clear that the amounts for these puposes in the NSF budget are quite inadequate to solve them. Therefore, whatever amounts are finally authorized and appropriated, there will, in addition be a role for NSF and the mission agencies to provide services to encourage other arrangements (as I have outlined above) to help solve these problems. I have noted that engineering and its process of developing technology and transforming the results of science into technology which becomes productive in industry, in agriculture, and in solving national problems, and the use of the resulting technology to make the goods and services that we sell and consume, is fundamental to everything that is meant by the term productivity. Indeed, it has traditionally been the fundamental trigger and support to U.S. economic prosperity, and certainly the means by which its products have been made competitive in the world.

There is considerable evidence that in some fields and portions of industry innovative and productive capabilities have slackened, particularly in comparison with some of our foreign commercial competitors. We need some means by which industries that have ceased to be as innovative as they might be, can be helped to regain their spirit and competitive force. Some means for providing a stimulus, a trigger, and some of the materials for new innovation seems to be needed. It is not clear that the current workings of the market place, dominated as they tend to be by the requirement for short term profit making, provide a stimulus to those innovative processes that inevitably take longer periods of time but are the basis for birth and rebirth of industries.

NSF may also have a role in this area by providing catalytic support of reseach. This should be cooperative between industries seeking innovative help and university graduate research and education which can assist in providing it. The combination of university research interests coupled with the practical requirements of industry seeking new products and new ideas, is likely to be healthy for both, but it appears that some kind of marriage broker is required in many cases. This seems a sensible and not overly expensive governmental role: stimulating a longer range view than it is easy for markets to take, and providing for stimulation of broad technology transfer and use. Such a program seems far more sensible to me than direct support or support by distorting market place trading arrangements; it is merely using public capabilities as a stimulus to the ability to compete.

The bulk of the engineering research that is supported by the U.S. government is that supported by the mission agencies: the Department of Defense, NASA, the Department of Transportation, the Department of Energy, etc. The role of NSF is to examine the field of research supported in this manner, and do those things that are required to round out the fields of research in those areas that make sense for technological and ultimate commercial development, but are not covered by immediate mission requirements, or are not otherwise immediately stimulated by industrial requirements. The philosophy I am suggesting is simply that there is a public interest in caring for the long-range future of engineering and innovation in a way which short term market forces do not do. This is a role of stimulation, of filling in areas that are uncovered, and providing for research and thought which is coordinative among areas that could be significantly stronger if working together.

From this point of view we welcome the reorganization of the National Science Foundation because it will provide a focus on engineering. This focus will enable it to examine the subject in a cross disciplinary manner, looking across engineering and in a way which looks at engineering from the point of view of national requirements and industry requirements. NSF can then focus upon an output of engineering research which both solves problems that exist and are developing, and lays a foundation for a bridge of problem solving to future problems.

The proposal for a National Technology Foundation was a proposal to accomplish this by a new institution. The refocusing on engineering by reorganization within the National Science Foundation can well accomplish the same ends, provided it is carried out vigorously, and has sufficient budgetary support in order to do its task in a real way. The engineering societies look forward to assisting the NSF in carrying out these purposes in any useful way that they can.

Before concluding, Mr. Chairman, I would like to make one additonal point, not necessarily connected with the NSF authorization. The type of national problem being discussed here today is basic for our economic life, and along with similar problems of engineering, science and technology will need to be addressed at the national, and the presidential level. The AAES and its societies believe that it is important for the President to fill the post of Science Advisor and Director of the Office of Science and Technology Policy. The President needs to have direct unbiased technical advise on technical problems immediately available to him. This is not a matter of the scientific and engineering communities acces to him, it is a matter of his easy access to them, and what they know, and can do. He can best get this through an advisor on his staff.

Mr. Chairman, thank you for your invitation to put forward our views. I will be happy to try to answer the committees' questions.

Mr. WALGREN. Dr. Paxton.
[A biographical sketch of Dr. Paxton follows:]

BIOGRAPHICAL SKETCH - H. W. PAXTON

H. W. PAXTON is Vice President-Research of the United States Steel Corporation. He received his B.Sc. and M.Sc. in 1947 and 1948 from the University of Manchester and his Ph.D. in 1952 from the University of Birmingham. In 1953 he became Assistant Professor of Metallurgical Engineering at Carnegie Institute of Technology, subsequently Carnegie-Mellon University, and became Head of the Department of Metallurgy and Materials Science and Director of the Metals Research Laboratory of Carnegie-Mellon in 1966. He was Visiting Professor in Metallurgy and Materials Science at Imperial College, London, in 1962-63 and at the Massachusetts Institute of Technology in 1970 and served two years as the first Director, Division of Materials Research, National Science Foundation 1971-1973. He was a consultant to industry from 1953 to 1974 and has authored many technical papers, primarily in the field of physical metallurgy. He also co-authored a book, "Alloying Elements in Steel," with the late Dr. E. C. Bain

Dr. Paxton received the Bradley Stoughton Award for young teachers of metallurgy in 1960. He is a Fellow of the American Association for the Advancement of Science, member of the National Academy of Engineering, Directors of Industrial Research, the Industrial Research Institute; Fellow of the American Society for Metals and The Metallurgical Society of AIME; Past President of TMS; Past Chairman of the General Research Committee of the American Iron and Steel Institute; and President-Elect of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

Dr. Paxton was selected as the 1978 ASM Edward DeMille Campbell Memorial Lecturer.

STATEMENT OF DR. H. W. PAXTON, VICE PRESIDENT-RESEARCH, UNITED STATES STEEL CORP.

Dr. PAXTON. Thank you, Mr. Chairman, Congressman Brown and ladies and gentlemen. It is a great personal pleasure for me to be here to offer my comments on the National Science Foundation authorization bill.

I am Harold W. Paxton, vice president of research for the United States Steel Corp., and also the chairman of the Science Policy Subcommittee of the Federal Science and Technology Committee of the Industrial Research Institute (IRI).

Members of the IRI include virtually all of the major companies in the United States with a continuing interest in research and development.

Since what I am about to say will be personal rather than official comment, I should perhaps also mention that for some 21 years I was a professor at Carnegie-Mellon University and also spent 2 years as the Director of the Division of Materials Research at the National Science Foundation. Thus, at least formally, I have some qualifications to speak on our subject today.

I have already mentioned that I will not be speaking officially for the Industrial Research Institute, but I would like to ask for the privilege of attaching two official position statements. The first is entitled "Industrial Innovation: The Impact of Federal Policies on Industry/University Relations", dated September 26, 1980, and the second is on "Government Economic Policies to Stimulate Innovation" and is dated November 27, 1979.

[The statements follow:]

INDUSTRIAL INNOVATION: THE IMPACT OF FEDERAL POLICIES ON INDUSTRY/UNIVERSITY RELATIONS

Position Statement by the Industrial Research Institute

To foster development of the new products and processes needed to help this Nation meet its economic and social goals, the Industrial Research Institute (I.R.I.) strongly supports increased interaction between industry and university research. Universities provide both the trained human resources and much of the basic scientific knowledge upon which innovation depends. Industry provides the ability to understand and to predict needs of the marketplace, and has the capability of developing the discoveries and inventions of universities into new products and processes needed by the public. Accordingly, I.R.I. urges that Federal policies be used to promote closer collaboration between our universities and our industrial organizations. To this end, I.R.I. recommends that the Federal government:

1. Provide Federal tax incentives to stimulate industrial support of university research and graduate education;
2. Encourage Federal funding agencies to manage their programs in ways that enhance coupling of universities and industry;
3. Adopt uniform patent policies for Federal agencies, providing that (a) title to inventions made using government funds in universities remain with the universities, (b) universities have the right to grant licenses, which may be exclusive or non-exclusive, as appropriate to encourage commercialization, (c) government receive a royalty-free non-exclusive license to practice such inventions for government purposes, and (d) government have the right to "march-in" and require licenses for such inventions which are not commercialized within a reasonable time;
4. Seek significant new input from the industrial and university sectors in developing forecasts of national requirements for trained human resources in the various scientific and engineering disciplines.

The Industrial Research Institute affirms the importance of continued direct Federal funding of basic research conducted primarily in universities. The National Science Foundation Program of Industry/University Cooperative Research Grants is especially commended, because it provides a vehicle for enhancing university/industry relationships. In contrast, I.R.I. views with great caution proposals to establish new "Generic Technology Centers," since there is a significant risk that such laboratories may become a self-perpetuating drain on national resources and lack the necessary inputs on market needs and opportunities to be an effective force in the innovation process. Accordingly, I.R.I. urges that such centers be funded only as a last resort, for those industries or technological areas with significant national impact, and then only with provisions for termination if financial support from the private sector is not forthcoming.

September 26, 1980

POSITION STATEMENT ON GOVERNMENT ECONOMIC POLICIES TO STIMULATE INNOVATION

INDUSTRIAL RESEARCH INSTITUTE

Industrial innovation is a natural and potent force in any free-market economy. The Industrial Research Institute (I.R.I.) believes, therefore, that specific interventions by the Federal government to stimulate the innovation process should *not* be required. What is required instead are a number of Federal actions to remove the economic barriers and disincentives to successful innovation that have been growing in number and intensity for the past three decades.[1-6]

These actions should include, first and foremost, those which would most directly improve the incentives and climate for industrial innovation, and reduce the policy uncertainties presently restraining the innovation process.

Specific Recommendations

1. I.R.I. urges coordinated, positive government action to control the basic causes of inflation. Such action is essential to unshackling industrial innovation. Because accelerating inflation adds to the investment costs required, and because the uncertainty of the true value (i.e., in deflated dollars) of the expected return is increased, inflation shortens the time and risk horizons of both entrepreneurs and management groups responsible for innovation decisions to the point where both the number and quality of innovation attempts, especially in high-technology areas, are severely reduced.[7,8]

2. Industrial innovation results in new products and new processes, which in turn create new industries and new jobs. None of these can come into existence, however, without the manufacturing plants and equipment needed to produce them, with the consequent need for vast sums of investment capital. For example, the average capital investment per manufacturing job in the United States now exceeds $50,000.[9] In addition, innovation in major established industries often results in obsolescence of plant and equipment before normally scheduled replacement. For these reasons, successful innovation places a double demand on availability of capital funds.

   I.R.I. therefore strongly favors Federal actions to increase the rate of capital formation in the United States (i.e., the national savings rate) as well as its availability to technically venturesome organizations and entrepreneurs. I.R.I. suggests that such actions include, but not be limited to:

   a. Phased introduction of modifications in, and/or alternatives to, the present progressive income tax with its numerous inherent biases against accumulation of savings and capital.[7,10] In this connection, I.R.I. notes that serious study of potential capital-incentive-taxation reforms was undertaken by the Treasury Department during the previous administration.[11]

b. Further decreasing the tax on capital gains in addition to the positive steps taken in the 1978 tax legislation, at least for initial equity investments in new technological ventures.

c. Modifying present tax regulations further to allow for accelerated depreciation allowances for plant and equipment and/or increased investment tax credits.

3. In the rare instances where benefits to society are estimated to be very high in relation to returns expected from the market, I.R.I. agrees that direct government subsidies of part or all of the innovation costs may be justified.

We caution, however, that the use of such subsidies to make up for inadequate incentives and availability of private capital for innovation will increasingly sap the flexibility and vigor of the private sector that historically has been the source of almost all major successful technological innovations. *For this reason, I.R.I. believes strongly that direct support and other government interventions into the marketplace should not be utilized as an excuse for failing to deal more directly with economic-incentive and capital-formation issues as recommended above.*

In the same view, I.R.I. believes that the most useful way to diminish the barriers and disincentives to innovation omnipresent in the present regulatory climate in the United States would be the maximum use of market-adjusting economic incentives, as opposed to legal restrictions and penalties, in attempting to meet regulatory goals. I.R.I. recognizes that the Environmental Protection Agency recently began exploring such incentives with its encouragement of marketable permits and emission taxes. We believe that all agencies should be legislatively or otherwise directed to follow this example.[12]

Finally I.R.I. believes there is a specific area where government action to stimulate positively the innovation process also could be useful, to wit: market aggregation and performance-standard setting by government procurements. In general, public-sector dollars spent to create a meaningful initial market for new technology and/or innovative products and services has done more to enhance innovation than monies expended in direct subsidies or other attempts to intervene directly in the process.

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November 27, 1979

Dr. PAXTON. The second of these statements primarily concerns itself with comments on changes in Government policies to encourage innovation. In the new climate here in Washington some of the comments on the ability to generate private support of innovation by policy changes seem particularly appropriate.

Concluding this rather long introduction, I would also like to mention that last week I had the privilege of attending the annual meeting of the American Institute of Mining, Metallurgical, and Petroleum Engineers, which is a society having approximately 80,000 members in these important disciplines.

I took the opportunity, knowing that I would be offering this testimony, to inquire as to the general health of my colleagues in the universities and how my industrial friends perceive the immediate and longer term future for hiring.

Obviously, the study which I made was not statistically representative, but I have to tell you that I came away very disturbed at the situation in which we find ourselves.

Put bluntly, we are finding shortages of good faculty members, particularly in the engineering schools, a shortage of U. S. graduate students, some of whom might become the faculty of the future, and substantial increases in undergraduate engineering enrollment, leading to classes much larger than desirable with the faculty available.

To me this does not look like a healthy picture for the economic health of the United States. The National Science Foundation is critical in helping to alleviate these problems. A primary NSF role is to foster research and graduate education by whatever means seem appropriate. NSF has the confidence of universities and can react on a reasonably short time scale.

I would think it would be most discouraging to many of those who are going to play a leading role in our Nation's future if NSF is subject to major budget cuts in its most vital areas.

I am in general sympathy with the goals of the new administration and recognize the problems implicit in special pleading. Thus, the comments which I will make are on the qualitative priorities as I see them.

I am not in a position to be able to make financial judgments on the information which I have available to me.

I am pleased to see that engineering has been given a "stand alone" focus within the Foundation. The engineering departments in the United States, I am sure, will join with me in welcoming this recognition of the importance of their disciplines.

It also seems appropriate to me to put applied science support into other areas of the Foundation. I am sure this move will generate a number of jurisdictional disputes, but in my experience this is something which NSF can be left to solve.

Moving on to the subactivity on industrial science and technological innovation, I can offer my thoughts on some, but not all the program elements.

Industry-university cooperative research projects have worked well in my experience and at, United States Steel, we have participated with a number of universities in such projects.

Nevertheless, I believe that valuable as these programs are, the chance that they would contribute importantly to technological innovation is only modest. They offer the opportunity to put two or more first-class investigators working in different settings on a problem of common interest. This can produce excellent results and perhaps lay the basis for future innovation; but in my view, since innovation is most commonly market driven, the results are more likely to be publishable research, available to all.

I have expressed myself previously in testimony to Congressman George Brown in 1979 on the role of industry-university cooperative research centers. Apart from a general feeling which I have that centers as such tend to take on a life of their own, I have considerable reservations as to whether these can be effective in meeting the needs of industry in generic technologies. I would highlight here a paragraph from the IRI position statement, appended to these remarks:

> In contrast, I.R.I. views with great caution proposals to establish new "Generic Technology Centers," since there is a significant risk that such laboratories may become a self-perpetuating drain on national resources and lack the necessary inputs on market needs and opportunities to be an effective force in the innovation process. Accordingly, I.R.I. urges that such centers be funded only as a last resort, for those industries or technological areas with significant national impact, and then only with provisions for termination if financial support from the private sector is not forthcoming.

While I have had some exposure to the "Small Business Innovation Research Program" and the "University-Based Innovation Centers", I am really not sufficiently familiar with them to feel confident in offering testimony. I believe there will be other speakers here who can help the committee much better than I can. As a general comment, however, I would remark that changes in the tax structure which free up funds to enable private decision on investment in the innovation process would be my preferred route to achieve many of the goals which these two programs seek.

Finally, it is my understanding that the proposed request from NSF for university laboratory upgrading—$75 million—is currently under close scrutiny and may be eliminated. For far too long, the laboratories in this country have been allowed to fall behind those in Europe and Japan. It is certainly possible to train good scientists and engineers without the most modern equipment, but it is very hard for them to compete internationally without such modern equipment. It is, unfortunately, also possible to defer such purchases until next year, and the year after, and so on, in the hope that the economic situation will eventually improve.

I believe that a decision should be made at this time to begin on this program, perhaps modestly, even if this involves making some cuts in support of people in the overall NSF budget.

There is a certain elitism in supporting only the very best universities and investigators, but if the choice were up to me, I would look hard at the investigators near the cutoff in funding support in various programs and provide funds for equipment from the savings by not supporting these people.

Mr. Chairman, I appreciate the opportunity of making these few remarks, and I would be pleased to answer any questions which you or others may have.

Mr. **Walgren**. Thank you very much, Dr. Paxton.

Mr. Brown.

Mr. **Brown**. I gather both of you gentlemen would agree that the reorganization in NSF focusing on engineering is a reasonable initiative to take and that it has at least the potential of meeting some of the problems we face in the engineering community.

Dr. **Frosch**. Yes.

Mr. **Brown**. I think that leads me to ask if we should make efforts to further consider our National Technology Foundation at least pending some analysis of the results of the reorganization. Do you have any views on that?

Dr. **Frosch**. It would seem to me, from my experience in the Government, that if, or as long as there was a continued push for a complete alternate, it would be probable that the full operation of the reorganization in NSF would not quite happen in a fully healthy way. NSF would feel as though it were under a continuing cloud, and probably some effort in the Foundation would be devoted always to the question of "What testimony was to be given on the new bill and the new entity", so I would be inclined to feel that would not be quite giving NSF reorganization a full chance to see what it could do.

If it did not do what the committee felt was important, or you, as sponsors of the previous bill felt were important, why then one could come back with the alternative. I am afraid it would be a little like trying to ride two horses going in different directions.

Mr. **Brown**. Mr. Paxton, any comment?

Mr. **Paxton**. Yes. I think technology is obviously one of our vital needs. But I am not sure that parallelism with the current National Science Foundation with its engineering group is necesarily the best way to provide such support.

Mr. **Brown**. Of course, I could take the opposite point of view, Dr. Frosch, that pursuing the National Technology Foundation initiative might encourage NSF to do even a better job, with a new focus on engineering?

Dr. **Frosch**. That is a possible hypothesis.

Mr. **Brown**. I take it that the AAES will do a vigorous job of monitoring the Foundation to see that it does an adequate job of carrying out this new program and that sufficient funding is alloted to it?

Dr. **Frosch**. We can certainly watch the funding. I doubt that we can affect it much. I expect that we will be working with the leadership of the NSF in discussing how the engineering community can help them in carrying out the responsibilities of this division.

So I would hope that we will be in that kind of degree participants.

Mr. **Brown**. I certainly hope so. I am sure the Foundation would encourage that. Of course, what we would hope in this committee is you would give us your own most objective advice as to whether you think NSF is meeting reasonably the needs of the engineering community and of the country with respect to showing some of the problems that have been described to us in engineering research and development and in education.

Dr. **Frosch**. We would certainly be happy to respond to the committee's desires for other testimony and comments as the situation develops.

Mr. BROWN. Dr. Frosch, it is obviously difficult to make many comments about a budget request which has not been submitted yet, but could you or would you care to make any suggestions or comments about the rumored changes in the National Science Foundation budget to be presented next week?

Dr. FROSCH. I guess the main point is that the problem, as I indicated in my testimony, appears to be larger than the budget provided for it to start with, so that even that budget implied other mechanisms being brought into play to solve it.

It is hard to see how cutting it further improves the ability of the available funds to solve the problem.

Mr. BROWN. Thank you.

Dr. Paxton, I think you are well aware that this committee, in fact Members of both the House and Senate, were quite critical of previous administrations for failure to act with regard to the innovation and productivity in the way IRI has suggested with regard to removing some of the Government inhibitions to innovations and stimulating the further accumulation of capital.

What has bothered me is a perception that maybe we have swung from one extreme to the other, that this administration, with its philosophical commitment, which I won't quarrel with particularly at this point, may, in putting its sole focus or largest focus on accumulation of capital, tax incentives, removal or easing of regulatory environment, have gone too far in omitting some of the support for areas which are not going to be met by the market system. Could you comment on that?

Mr. PAXTON. I think I would have two comments on that, Mr. Brown.

First, while I would have to say we are generally in sympathy with the thoughts of the new administration, the actual practice has not yet arrived and it may not be that it goes as far as you fear.

On the second point, I think the ability to generate more private enterprise discretion in funding, would lead to support of, for example, the science and technology in universities purely in self-interest, if nothing else. There is nothing that drives a company like self-interest, and this is very much in our interest.

Mr. BROWN. As a result of our understandings of the complexities of the innovation and productivity problem, we were beginning to focus on a number of different aspects. For example, antitrust problems that prohibited joint research in industry. That may be an issue for this administration. The breaking down of the adversarial relationship so we could begin to do some at least common or joint thinking between industry and Government and universities with regard to global marketing opportunities that need to be addressed.

I worry that the attitude now may be: Well, industry is going to have its head here, you might say, it is going to be given its own opportunity to solve these problems and we may continue with some of these adversarial relationships, for example, which would be highly unfortunate.

Let me give you an example. I may be wrong, but I don't think it was entirely a matter of Government posture that caused Chrysler to suffer the financial difficulties it has. I recognize that the Government may have been partially responsible, but there may have been some poor decisions by the industry involved.

Mr. **Paxton**. Yes.

Mr. **Brown**. And the need is not going to be met by just rescuing Chrysler from its own mistakes.

Mr. **Paxton**. Yes.

Mr. **Brown**. If we follow the philosophy of this administration, we are not going to bail out Chrysler in the future.

Mr. **Paxton**. Right.

Mr. **Brown**. We are not going to bail out your company.

Mr. **Paxton**. That is right.

Mr. **Brown**. Are you willing to live with that kind of situation?

Mr. **Paxton**. Yes.

Mr. **Brown**. Well, we are going to have an interesting scientific experiment then.

Mr. **Paxton**. Those are the kind we like to conduct.

Mr. **Brown**. Thank you, Mr. Chairman, that is all.

Mr. **Walgren**. My understanding is U.S. Steel has diversified substantially.

Mr. **Brown**. I hope they are putting a lot of money in R. & D. [Laughter.]

Mr. **Walgren**. I wanted to ask, just to pursue the view that the industry-university cooperative research projects are perhaps not working quite as well as we might hope with respect to contributing to increased technological innovation.

Dr. Frosch testified regarding relationships between the universities and the engineering-industrial community. Would the program envisioned by him provide a good opportunity to bring about the kind of equipment sharing and part-time professors and the relationship that it looks like we should pursue if we are to add strength to the educational process in the short term?

Mr. **Paxton**. Yes, it does. I perhaps might amplify a little bit on my statement. The work that is done in this area does enable much of what Dr. Frosch was speaking to, to be carried out. The work that I have seen is really first-class research.

My point was that, of itself, having someone in the university work with someone in industry, will not necessarily improve innovation. Even though it is very fine research, and we have had some excellent back and forth between the universities and industry on this.

Mr. **Walgren**. Well, thank you very much. We certainly appreciate your statements and we hope that we will give them some real weight in the process of considering where we go from here.

Mr. **Paxton**. Thank you very much.

Dr. **Frosch**. Thank you.

Mr. **Walgren**. Our last panel consists of Dr. Dwight Baumann, Director for the Center For Entrepreneurial Development at Carnegie-Mellon University, and Mr. Robert Havlick, Director of the Florida Innovation Group. I appreciate your coming before the committee today. Any written testimony you have will be made part of the record and you could proceed by summarizing as briefly as you feel is proper.

You have the microphone, Mr. Havlick, so why don't you proceed first.

[A biographical sketch of Mr. Havlick follows:]

J. ROBERT HAVLICK

1979–present: Director, Florida Innovation Group, Tampa, Fla.

1978 to 1979: Urban Advisor, ERD–EMCOL International, Porter, Ind.

1971 to 1978: Senior Vice President, Public Technology, Inc., Washington, D.C.

1965 to 1971: Director, Information Center, International City Management Association, Washington, D.C.

1964 to 1965: Assistant to the City Manager, LaGrange Park, Ill.

1962 to 1964: School Teacher, Elmhurst, Ill.

Education

Northern Illinois University.
Degree: M.A.
Major: Public Administration.

Western Illinois University.
Degree: B.S.
Major: Social Sciences.

Selected publications

"Local Government Use of Science Technology Advice," Municipal Year Book, 1971.

"Using Aerospace Technology for City Problem-Solving," Public Management, February 1971.

"Local Government Finances: Trends and Projections," Urban Data Service, October 1968.

"Fire Prevention: Codes, Enforcements, and Inspection," Urban Data Service, June 1969.

"The American City and Civil Disorders," Urban Data Service, January 1969.

"Recruit Training: Police Chiefs' Dilemma," Public Management, December 1968.

"Police Recruit Training," Management Information Service, June 1968.

"Police-Community Relations Programs," Management Information Service, November 1967.

"Tactical Planning for Crowd and Riot Control," Management Information Service, August 1966. This report has become a standard for use by several police departments. For example, it was distributed to every law enforcement agency in the State of New York by the State Office of Local Government.

"City's Goal: To Stop a Riot," Public Management, August 1966.

"The Computer Challenge," Public Management, July 1966.

"Will Federal Grants Provide the Answers?" Public Management, July 1966.

"Training and Equipping Police Crowd and Riot Control Officers and Units," Management Information Service, May 1966. This report has also become a standard, with similarly wide distribution.

"Police Administration—Police Training for Crowd Control," Municipal Year Book, 1966.

"Centralized Municipal Communications Centers," Management Information Service, November 1966.

"Space Age Challenges City Management," Public Management, November 1965.

STATEMENT OF J. ROBERT HAVLICK, DIRECTOR, FLORIDA INNOVATION GROUP

Mr. HAVLICK. My written statement discusses the concept, philosophy and general goals of the Florida Innovation Group. Rather than restate what I have already written, I would like to spend this time discussing three areas; the first being some of the actual program activities of the Florida Innovation Group which demonstrate our commitment to work cooperatively with small business, the large industrial sector, and local governments.

Second, I will talk about our Innovation Group's financial strategy and our intent to become independent of Federal support over a 5-year period.

Then, third, I would like to say a few words about the importance of the NSF support to date and its continuing importance in the future.

All of my comments are made within the context of the fact that the Florida Innovation Group is only 8 months old in terms of implementation.

We had a 6-months planning grant and now we are 8 months into our implementation period. The total amount of moneys we are talking about in regard to NSF support to date is $80,000. We are not talking about a large Federal investment in regard to the kinds of activities we have been able to undertake.

First, in regard to actual programs, I have heard a lot of discussion today about small business innovation, about industrial innovation, about local government involvement in the R. & D. process, but I have not heard very many specific examples of what can or cannot be done in terms of an innovation group being a catalyst. Catalyst is an important word to define an innovation group because Florida Innovation Group is not trying to become a large research and development entity to duplicate resources that are already available in the private sector, university sector or in local government itself.

Our strategy is to stay small and play a catalyst role. For example, the Florida Innovation Group is currently working with about 15 small businesses in and out of the State of Florida who have laboratory technology ready to come into the marketplace. Almost without exception these small businesses have not looked upon local government as a target marketplace for their products. The reasons for this are many, but the most driving is that the local marketplace is disaggregated and difficult to enter. Competitive bid requirements cause high risks in bringing new products into this market.

Perhaps most importantly the local government is not looked upon as a place to take high risks with new technologies.

We have been able to begin to interface with small companies. A specific example involves a company that has taken microcomputer technology and formated it into a portable meter reader. With this device a meter reader can go up to your house, read your meter, punch in your reading and print out a bill on the site. This is lab technology which is still being refined and will be ready for field use in about 6 to 8 months.

We have interfaced this small company, Portable Computer Systems, with Orange County, Fla., Orlando, St. Petersburg, Pinellas County, Clearwater, and Jacksonville. In order to explore the attractiveness of this technology to government operations and to access the cross-effectiveness of this technology and these governments' willingness to spend their dollars to participate in tests.

Without exception, these governments are willing to spend their own moneys to buy this technology and test it as a group. This does a rapid thing. It spreads the risks among several local governments so no single local government takes the total risk of failure which as you can expect is unpopular if you are an elected or appointed official in a city or county government.

The potential dollar savings we are talking about here are incredible. If you are a city of around 75,000 population and you have

50,000 water meters, which is about what you would have if you were in that population range, you will save $70,000 a year just on postage with this technology. That savings would return the investment in this equipment the first year.

Thus, we can demonstrate to local governments that if they invest in this technology, during the first year they will obtain a near 100-percent return on investment. In subsequent years the savings will be net.

You also get a one-time accelerated cash benefit from increased cash flow. This is about $148,000 a year for these 50,000 accounts. So a government of around 75,000 population can save in excess of $200,000 the first year they implement this technology.

So what does this kind of experiment do?

It saves money for local government. It provides a company with market entry. This company is now getting geared up to go into production. They are going to locate their manufacturing facilities in the Tampa-St. Petersburg area and hire people so we are creating jobs and profits.

Now, this small business has no Federal support for anything and are using their own capital to develop the technology.

FIG is the catalyst using small amounts of NSF money in bringing these interests together and this is a case where I think we will have positive results.

There are at least 10 other companies with technologies ranging from erosion control, a difficult problem in Florida, to companies with very, very exciting energy-saving technologies that we are working with in the same way. They have prototype technologies and want to get them into local government. The Florida Innovation Group is able to aggregate the local government market and accumulate test moneys. The companies bring in the technology and local governments evaluate it. If it works, we have a new industry that can begin production.

I think it is important to understand that there is nothing you can think of that is mass produced or a service provided that in some way, shape or form local governments do not buy or use. So there is a very appropriate test ground here for prototype technologies. That local governments are major consumers of goods and services is a major part of our philosophy as we try to convince companies that local governments can provide a marketplace for their products.

On a larger scale, we have been working with General Motors Corp. for well over a year in a major five-State, 27-jurisdiction program. This effort brings the technical skills of General Motors in the energy area into city and county halls to assist these governments in creating the most comprehensive analysis they have had to date on their total energy environment today, and projected to the year 2000.

The quality of resources General Motors has brought into city hall are the kinds that these individual governments cannot afford to go out and purchase on their own. In every single case, these governments aggregated moneys to provide some support to GM, that GM matched on 5- or 6-to-1 basis.

In every one of these 27 governments we had to go before city council and explain the private-public partnerships and explain why a company like GM would want to make these kinds of commitments, what was in it for GM and for the local governments.

In my written testimony, I have provided some of our observations as to why this program did go forward and why we feel it has been an overwhelming success. FIG, GM, and the participating jurisdictions have demonstrated that a lot of the suspensions and antagonisms that Congressman Brown alluded to earlier can be overcome as you build private-public sector partnerships.

Also, a division of General Motors, Harrison Radiator, has been working on new prototype solar flat-plate collectors for several years and is now determining whether or not to enter the marketplace. They have installed their collectors on their own corporate structures throughout the United States, but none on any non-General Motors structures to date.

As part of this experimental GM/FIG program four of the participating governments—Rochester, N.Y., Fort Lauderdale, Pompano Beach, and Broward County, Fla.—have installed this test hardware on selected public facilities.

In this program we have an evolving technology that may or may not come to the marketplace, based upon future corporate decisions of Harrison Radiator. The local government tests will provide data which will be provided to GM as they make their important decision as to whether or not to proceed to the marketplace.

I can provide other examples of what we are doing, but I think these are indicative of the major commitment of our program to be a bridge between the public and private sectors.

As I indicated, we are in the first year of what we hoped would have been a 5-year National Science Foundation commitment to the Florida Innovation Group. FIG is on record at NSF that by the end of the fifth year we would anticipate zero continuing support.

It is our position that an innovation group should have a strategy to demonstrate its local attractiveness so it can be supported at the end of the fifth year by other resources. We implemented a dues structure in Florida by which we went to local governments and said "You must pay your fair share of this process."

In 6 months we have over 20 governments supporting FIG financially. That support more than matches the NSF contribution to date. We are developing a strategy to bring private sector support into the program as well. We are confident that at the end of the fifth year we will have a program that is 100 percent independent of Federal support. We are on schedule with that as of now.

I think it is the responsibility of every innovation group to have the same kind of strategy for withdrawing from NSF support.

What does NSF support provide for us?

Obviously, it provides program stability as we build our capabilities. It is support money that allows us to build a small staff while we go out and build our programs and other types of financial support.

We are finding in Florida that perhaps even more important than this program stability is credibility. We found that the NSF program support initially provided enormous credibility when we briefed city and county councils and sold the program for their jurisdiction's financial participation.

We are also finding that NSF support provides credibility at the State level where we are working closely with the Governor's office and his energy program in Florida.

We found out when we incorporated and applied for our nonprofit status at IRS, that the participation of NSF alleviated some of the difficulties we otherwise would have had in achieving our nonprofit status.

NSF support spreads the financial risk so we can go to local governments and say: "Put money in now. If you put a dollar in, at least 50 or an additional 60 cents will come from NSF, so you are spreading your risks not only in relationship to the NSF money, but in regard to contributions from other local governments as well."

So I would hope Innovation Groups are not an endangered species based upon some of the things I heard this morning. Innovation Groups complement an awful lot of what we are hearing NSF management is interested in pursuing, especially in the areas of industrial and university innovation. In Florida we have a major program underway linking Tyndall AFB, the University of West Florida, and Escambia County in the area of refuse collection. FIG is committed to working with innovative entities in the university as well as the small business community. For the small amount of NSF investment in Innovation Groups and the returns to date it would seem that the continuance of NSF's Intergovernmental Programs should be a given.

I thank you for this opportunity to explain the programs and philosophy of the Florida Innvoation Group.

Mr. WALGREN. Thank you very much.

[The prepared statement of Mr. Havlick follows:]

Statement Prepared For

Sub-Committee on Science, Research and Technology

by

The Florida Innovation Group

J. Robert Havlick

March 5, 1981

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The Florida Innovation Group

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March 5, 1981

The Florida Innovation Group and its participating local governments thanks the Sub-Committee on Science, Research and Technology for this opportunity to explain our programs and the important role NSF's Intergovernmental Program has and continues to play in our development.

Introduction

The general impression in the United States as we enter the 1980s is one of recession, inflation, shortages, futility, and frustration. Local government is viewed as entering a decade of tax revolution, service cutbacks, labor unrest, and fiscal constraint. Contrary to the doom-sayers, there are those who view the coming decade as the most challenging since the settlement of our country. The Florida Innovation Group and most government and industry leaders in Florida view the 80s as a decade of opportunity for innovation and change, not retreat. We also believe that the products and resources from our nation's science and technology community hold many of the answers to our apparent problems.

The major theme of the Florida Innovation Group's 1980s program is aggressive cooperation among local units of government and between government and the private sector. Florida recognizes, because of its fragile environment, energy vulnerability, incredible growth, and presence of high technology resources, the critical role science and technology will play in the future viabilty of the state. If local governments are to continue to be effective mechanisms for the delivery of services, the use of new technologies is almost mandatory.

The diversification of science and technology needs in Florida with its large urban concentration and high technology base, its large rural areas and rich agricultural and forestry base, its long shoreline and extensive swampland, and fragile, physical and ecological environments provides FIG numerous opportunities to bring university, industrial, and federal technologies to the task of local problem solving.

Florida's state government and its 67 counties and 387 incorporated cities and towns face the dilemma of rapidly increasing population and the accompanying increased demand for services amidst a statewide atmosphere of hold-the-line on taxes. It's this type of environment which forces local and state units of government to look beyond the normal ways of doing business in order to maintain high levels of service with scarce resources. Florida's local governments have, as a result, been willing to innovate as has the state. Examples of such attitudes are reflected through the leadership the state and localities have shown in experimenting with metro government (Dade County), governmental consolidation (Jacksonville-Duval County), and charter counties (Broward and Volusia). Several cities are now considering, or are currently experimenting with, contracting certain traditional public services with private firms (fleet maintenance, janitorial services, public works activities, and, even more frequently, waste collection).

The move in Florida county government toward professional administration has brought top-quality career professional managers into county government throughout the state. The majority of the state's cities are managed by career city managers or chief administrative officers while cities such as Orlando, Tampa and Jacksonville have charters which allow for full-time elected administrators (mayors).

Deficiencies in Local Government Use of Science and Technology

During the planning phase for the Florida Innovation Group, several deficiencies in the science and technology process became apparent:

1. Non-existing communication mechanisms among local governments and between local governments and private sector for continuous, effective information exchange on science and technology issues, products, legislative programs, etc.

2. Lack of awareness in government and the public regarding the high potential science and technology offer. Few city officials enter their offices in the morning and say, "Now, how can science and technology assist me today?" Few voters mandate higher use of science and technology. The "cause and effect" relationship of higher use and support of science and technology isn't clear.

3. A coordinated policy to inform the public through the media is needed. The Florida media are very responsive to science and technology issues when properly informed.

4. There exists no "depository" of working solutions to local government needs, which leads to duplicative expenditure of

resources by local and state government through "re-creation of the wheel."

5. No local government cooperative product development through shared funding approaches.

6. No statewide agenda and priority setting by local governments in concert, which could lead to better allocation of scarce state and federal R & D resources.

7. Lack of local policy coordination in the area of science and technology, which leads to a fragmented state approach to local problem solving.

8. Small business entrepreneurs have a difficult time in adequately assessing the local government marketplace and a nearly impossible time in entering it with new products.

9. Large industry does not have access to an aggregated local government clientele which will assist in product testing, product development and ultimately purchase of proven cost-effective products and services.

10. No existing institutional mechanism which can be the "technology broker" on behalf of local and state government. Such a "broker" could perform a wide range of functions, including:

    a) Matching solutions with needs.

    b) Adapting technology to meet state and local needs.

    c) Participation in "testing of innovation" to help remove political risk of failure.

    d) Aggregation of financial resources to assist in instances when lack of capital stalls or stops a specific innovation.

Research Questions

In this, its first year of implementation, the Florida Innovation Group is pursuing solutions to the above issues within the context of several research questions. Such issues or questions are concerned with topics which range from financial viability to program strategy. The answers to the following specific research questions will provide the future operating and program structure for FIG.

1. How does the Florida Innovation Group implement a short and long term financial strategy which will decrease dependence upon the National Science Foundation while increasing its financial dependence upon local governments, the state government, private

corporations, private foundations, and others as appropriate? Attachment A is a discussion of the financial options as currently viewed by FIG.

2. What are the most equitable formats through which to formalize relationships between FIG and the small business community in regard to such issues as:

    a) Cooperative hard product development?

    b) Cooperative soft product development?

    c) Product testing?

    d) Local government market entry?

    e) Licensing arrangements?

3. Is there a catalyst role for FIG in the area of identifying local government-developed products and effecting transfers to other governments?

4. What is the best model for program relationships among small businesses, large industry, local governments, and FIG? What forms should such partnerships take? What are the acceptable returns of such cooperation for local government, industry and FIG? How are the start-ups of such cooperative efforts financed? Attachment B discusses three public/private model approaches currently being tested by the Florida Innovation Group.

5. What are the potential linkages between FIG and the Federal Laboratory Consortium? Using the Tyndall AFB lab as a test, are there useful products in the lab system for local governments? How are such products identified and transferred?

6. Can an Innovation Group, through a role as coordinator and catalyst, impact statewide policy re new technologies? For example, can FIG play a significant role in Florida in the development of a local government statewide strategy on such technologies as solar energy, alternate fuels, shoreline erosion prevention, etc.?

7. During the implementation of the Florida Innovation Group, it will be necessary to identifv and implement the most useful functions for FIG. Such functions for FIG could include the following:

    a) Be a catalyst for product exchange among local governments?

    b) Participate in actual technology development?

c) Provide small business with market entry for new products?

d) Be a technology interpreter/translator for local governments?

e) Provide on-site technical assistance to local governments?

f) Develop and implement a technology information exchange?

g) Develop regional offices in order to be closer to its ultimate client groups - both government and private sector?

Expected Consequences of Florida Innovation Group Programs

In addition to the general benefit of encouraging city, county, and state governments in Florida to more effectively use the available scientific and technological resources in solving their on-going problems, FIG should provide positive impact in several additional areas. These include:

1. Local investment in research and development. Through its fee structure, FIG hopes to encourage Florida local governments to participate financially in a statewide science and technology program. In addition, special projects are envisioned which will call for additional investments and money by local units of government. An example of such a program and the financial investment aspects is illustrated by the following current FIG program: In Broward County, Florida, FIG brought together five cities plus the county in an energy program with General Motors. The cities and county are investing $37,500 in the program with GM contributing approximately $150,000. The end products of this effort will be short and long-term energy plans for each of the participating jurisdictions and important marketing information for GM, which will lead to future GM/local government cooperative projects. This Florida program has been duplicated in four additional states with FIG as the catalyst. In economic terms, FIG through its efforts with General Motors and local governments in Florida and four other states was able to influence the following investment:

	Local Investment in GM Program	GM Investment
Florida	37,500	150,000
Four Other States	100,000	600,000
TOTAL	$137,500	$750,000

The total of the above is $887,500 The total NSF investment in FIG to date is $80,000. This single project demonstrates how the NSF monies acted as a catalyst for a return of more than 10 to 1. In addition, the significance of this project is great enough that the U.S. Departments of Housing and Urban Development, Transportation, and Energy have all expressed interest in participating. This total does not even try to reflect the potential dollar savings in energy costs from the program.

2. Private sector investment. As Number 1 above illustrates, private sector investment in local government problem solving is not only possible but can be quite significant. It's a major responsibility of FIG to demonstrate to the private sector that such up-front investment will ultimately provide returns in the form of new and/or expanded business.

3. University partnerships. Current research and development relationships between university-based resources and local government are often tenuous. FIG, acting as a linkage and project coordinator, should be able to access university talent and link it with local needs.

4. Local product exchange. One of the cheapest and quickest means to bring products to local government is though product exchange experiments with other units of government. A basic operating premise of FIG is that local governments themselves are key innovators in the science and technology system and, as such, have a vast number of products to share among themselves. FIG plans to be a catalyst in matching such products with needs. The potential benefits to local governments from such an effort could include:
   a) Recipient cities and counties save development costs while implementing new products.

   b) Development jurisdictions may receive "product fees" which give recognition to quality of their products and, over time, will return some or all of their development costs.

   c) Quick entry of several products into the system since lengthy development time has already been expended.

5. Cooperative local product development. Many current problems facing government are generic in nature but the fragmented nature of local government usually discourages cooperative problem

solving. It is not uncommon for a city to conduct innovative programs without its adjoining municipalities' knowledge. FIG is a natural mechanism for the promotion and conduct of such cooperative programs. Advantages to the local governments in such cooperative ventures would include both cost savings and dilution of risk.

6. New markets for small business. Recognizing that most new innovative products originate in small business, it is incumbent upon FIG to test the means by which such products can be tested and purchased by local governments. Such a FIG activity could accelerate the introduction of new innovative products into local governments while, at the same time, assisting small business in overcoming many of the barriers involved in market entry.

7. Product testing and market aggregation for large industry. Large companies seldom think of local governments as testing grounds for prototype products. Also, because of mutual suspicions, it is rare that large companies enter into research and development partnerships with cities and counties. Through its preliminary experiences with companies such as General Motors Corporation, R. L. Polk & Co., Sperry Systems, and Harrison Radiator, FIG recognizes the opportunity to act as a catalyst in bringing the industrial and public sectors together. Such partnerships can benefit local government by: increasing its access to highly technical resources; providing it a voice in new product development; expanding its technology horizon through exposure to different ideas and ways of problem solving; improved services and lowering costs through the more effective use of technology. Private industry benefits by: more direct early involvement with the ultimate technology user, which could lead to a better understanding of needs, thus better products; direct access to "real" marketing information in the local government sector; costsharing of prototype development; tests of products in the actual operating environment; and "built-in markets" for products which evolve from the process.

8. Market diversification for existing products. Many companies have existing products which are currently not being marketed in the public sector. Reasons for such non-marketing include unfamiliarity with the public marketplace, fear of the diversification of the public market, inability to identify and approach the correct entry point, lack of knowledge regarding the public procurement process and the laws governing it, and lack of

recognition of the market's size. FIG can and will assist companies in overcoming these barriers and in the process will provide business with new market potentials while providing goverhment with problem-solving products.

User/Client Interest in Florida Innovation Group Programs

During its planning stage, it became apparent to FIG that, in addition to its primary user community of local government, several other user groups existed. These would include the university system, state government agencies, small business community, private industrial (big business) sector, chambers of commerce, public interest groups, trade associations, federal laboratories, and the media.

The major immediate objective of FIG in sorting through the above was to establish itself first with the primary user, local government. An advisory board was created and twenty-two city and county managers and elected officials representing jurisdictions geographically dispersed throughout the state were invited to serve. The participation of this committee in FIG activities provides FIG with its preliminary base of governmental support.

The other potential user groups have a range of interests in participating with FIG. Examples include:

1. A major university is working with FIG during the testing and evaluation of a Federal Laboratory system for improving solid waste collection.
2. A local university has placed a student intern in FIG offices.
3. Several universities have requested FIG involvement in and support for proposals to the state and federal government. A major FIG requirement for such participation is that such proposals enhance the university's research capabilities while providing local governments with useful products and information.
4. FIG has and will continue to intereact with such state agencies as Energy, Transportation, Economic Development, Community Affairs, etc. To date, FIG has acted as a catalyst in bringing together local governments and state agencies on research and development issues of common interest. On a selected basis, FIG has also introduced private sector companies to specific state agencies in order to initiate either joint projects or public use of new and/or

existing products. Also, the Florida Innovation Group with the support of the Governor's Energy Office sponsored the first Florida local officials' energy conference in December, 1980. As a result of this meeting a state-wide Florida Energy Official's Association is now being created with FIG as the secretariat.

5. FIG has had discussions with small businessmen regarding potential cooperative programs. For example, one midwestern company is interested in having FIG put together a Florida program for the testing of its product. Another local company is interested in FIG providing advice regarding local government market entry. This company is willing to conduct test demonstrations of its products and is also willing to enter into a formal agreement with FIG.

6. During its planning period, FIG has been able to enter into program relationships with major private companies and units of local government. Companies such as General Motors, Sperry Systems, R. L. Polk & Co., and Price Waterhouse & Co. see FIG as a useful mechanism for "trusted entry" into local government and as an on-going partner to assure the cooperative private-public partnerships stay focused. FIG can be an effective "translator" for the private sector during its program activities with local government as well as a catalyst to assure new program opportunities are responded to.

7. Chambers of Commerce are key organizations through which to reach the business community. FIG's planning stage was conducted through the Tampa Chamber of Commerce. While now separately incorporated, FIG plans to maintain relationships with not only the Tampa Chamber but similar organizations throughout the state. The knowledge regarding products and processes which exists in Chambers' membership probably contains innumerable immediate solutions to many local government problems. The challenge is to access and match the two in an organized manner. FIG will attempt to match local government and chamber interests.

8. The Federal Laboratories, especially those in Florida, represent a major element in an effective FIG operation. These labs can be used to access a wide range of potentially useful DOD products which may have application in local government. FIG is developing a test program with a Florida-based lab to transfer a DOD development technology to a local unit of government.

9. The Florida-based media, newspaper, television, and radio are aggressive users of the information FIG can generate on all types of local projects. FIG activities in energy have been widely covered in Florida media and FIG plans to develop a media strategy which enhances public understanding of science and technology.

All of the above examples represent involvement to date of FIG user and client groups. All this activity is organized to focus ultimately on the needs of FIG's true client, Florida local government.

This overview of the Florida Innovation Group is intended to show not only the range of programs and issues for an Innovation Group but also the complexity of issues which an Innovation Group must resolve as it evolves into a viable entity.

The National Science Foundation's Intergovernmental Program has been a critical factor in the start-up and development of the Florida Innovation Group. Without the assistance this program provided during the planning period and its current support during implementation, the Florida Innovation Group would not be in existence. In addition, the other networks the Intergovenmental Program partially supports makes it possible for us in Florida to reach into other states in an organized manner for information, advice, and actual technologies.

As has been stated previously, in Florida we are committed to a five year plan during which our dependence on NSF support will diminish annually until it reaches zero at the end of the fifth year. In Florida, we are right on schedule with this strategy.

While we do support the efforts to balance the Federal Budget, we would hope that in the case of NSF the budget reductions will be undertaken with equity. The total loss of the Intergovernmental Program at this time will bring to an end some of the experimental efforts to bring the benefits of science and technology to local governments. The probable loss of productivity at the local level and the likely loss of the local government marketplace for evolving technologies from the small business community seems a high price to pay for such a small continuing federal investment.

In Florida, we feel that the programs of the Innovation Group are well focused, our financial strategies are sound, and the benefits of our efforts are and will continue to be of increasing interest to the public and private sectors. Our only concern is that NSF be allowed to meet its three to five year commitment to us and other Innovation Group programs so we can continue to meet our commitment to the local and private sectors in Florida and throughout the United States.

In addition, we would hope that NSF continues its commitment to applied science. While those of us working with local governments don't always understand the discussions which occur in Washington over applied vs basic research, it does seem to make sense that strong programs are needed in both disciplines. Recognizing that NSF's primary mission is the support of basic research, we still hope that it is recognized that a strong applied research program enhances basic research expenditures. More importantly, a strong applied research program for local government which feeds off basic research results strengthens the entire process while solving pressing local government problems. We assume that the NSF reorganization will result in a strengthening of NSF's commitment to applied science.

Throughout the above discussion regarding the Florida Innovation Group the commitment to work in partnership with small business was indicated. Small business and innovation are almost synonymous in the history of our country. It would seem that NSF would and should be dedicated to the nurturing of this innovative environment while not stifling it with bureaucracy. The future viability of our country may well depend upon the innovative capacities of small business. The NSF should design and implement programs which enhances the growth of these capacities.

In addition, a strong and independent Innovation Group network which is able to access these innovative capacities in small business and federal laboratories and apply the results in local governments across the land would seem to be in the best interests of all of us. Thank you.

Attachment A

Florida Innovation Group

Private Sector Strategies

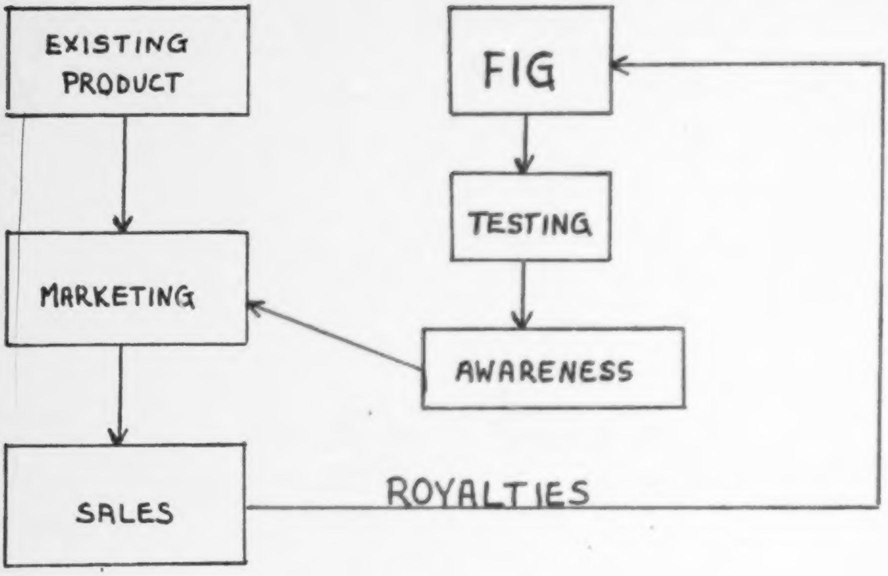
Probably the most challenging yet difficult mission for FIG is development of mutually productive programs with the private sector.

FIG's current thinking involves three models for working with the private sector.

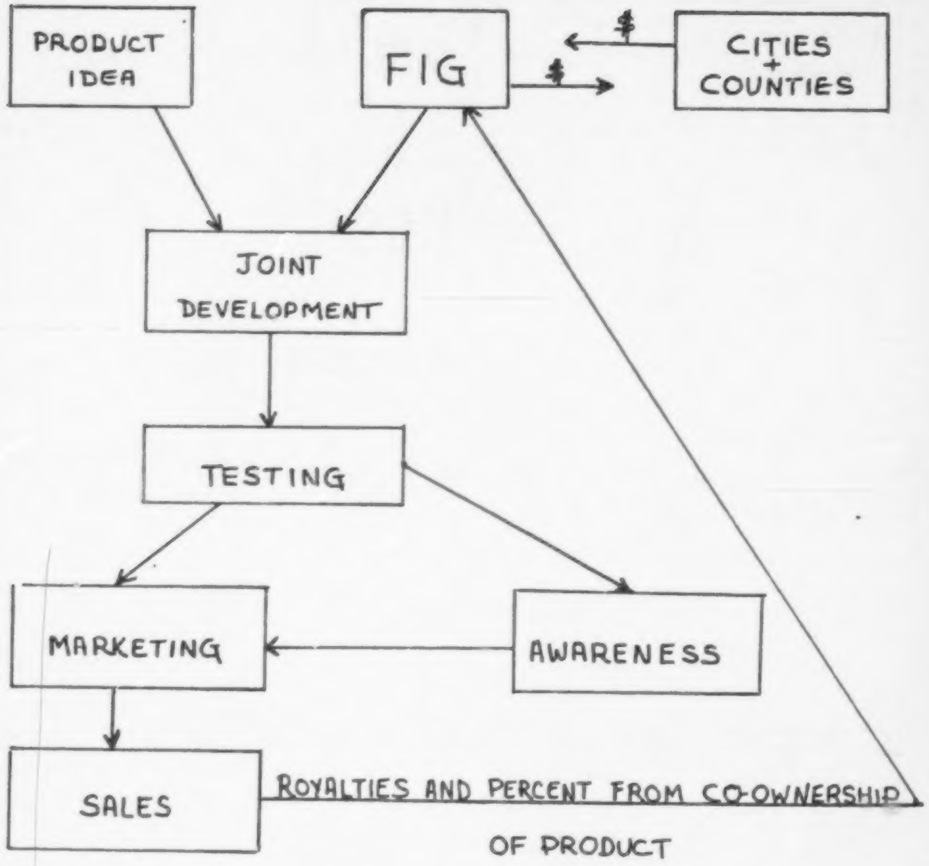
The first approach (Figure I) involves The Florida Innovation Group cooperating with a private company in developing a test program for its products in a local government environment. FIG, in cooperation with the local government and the company, would set up the test criteria which the local government would agree to follow. Cost of the product would vary on a case by case basis. In some instances, either FIG, or local government would pay the retail cost for the product, and in others, the private company may offer to discount the product during the test phase, and in other cases, the company may even provide the product at no cost in order to have the test conducted. To date, FIG has found one of the first two options as the most likely. However, under the third option, a small company is providing a product directly to a city for a demonstration project. Once the testing is concluded, the appropriate test results will be provided back to the company for use in its marketing program. FIG, through its continuing interaction with local governments, could create an awareness of the product and test results. When interest in their products is expressed to FIG by local government officials, such interest would be passed on to the marketing people in the company for follow up, and possible sales. When sales are made in the local government environment, royalties would be returned to FIG. The amount of such royalties will be negotiated on a case by case basis.

FIG staff is currently in the discussion stages with a few companies regarding the relationships as defined by this model. By the Summer of 1981 several field test experiments with at least 3 small companies will be underway.

The second FIG approach is joint product development (Figure II). In this approach, a private company could come to FIG with an idea for a specific product or project and request that FIG act as an intermediary with local government in order to assist the private company in putting together a jointly financed product development program. This model could also work in regard to cooperative ventures with the private sector in conducting feasibility studies, building major facilities such as an alcohol fuels production plant, etc. This concept operates under the assumption that a small group of local governments would provide seed money, through FIG, for a joint development activity. Once the product or system is developed, it


EXISTING PRODUCT
FIG
TESTING
MARKETING
AWARENESS
SALES
ROYALTIES

I. PRODUCT TESTING / MARKETING ENTRY


PRODUCT IDEA
FIG
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CITIES + COUNTIES
JOINT DEVELOPMENT
TESTING
MARKETING
AWARENESS
SALES
ROYALTIES AND PERCENT FROM CO-OWNERSHIP OF PRODUCT

II. JOINT PRODUCT DEVELOPMENT

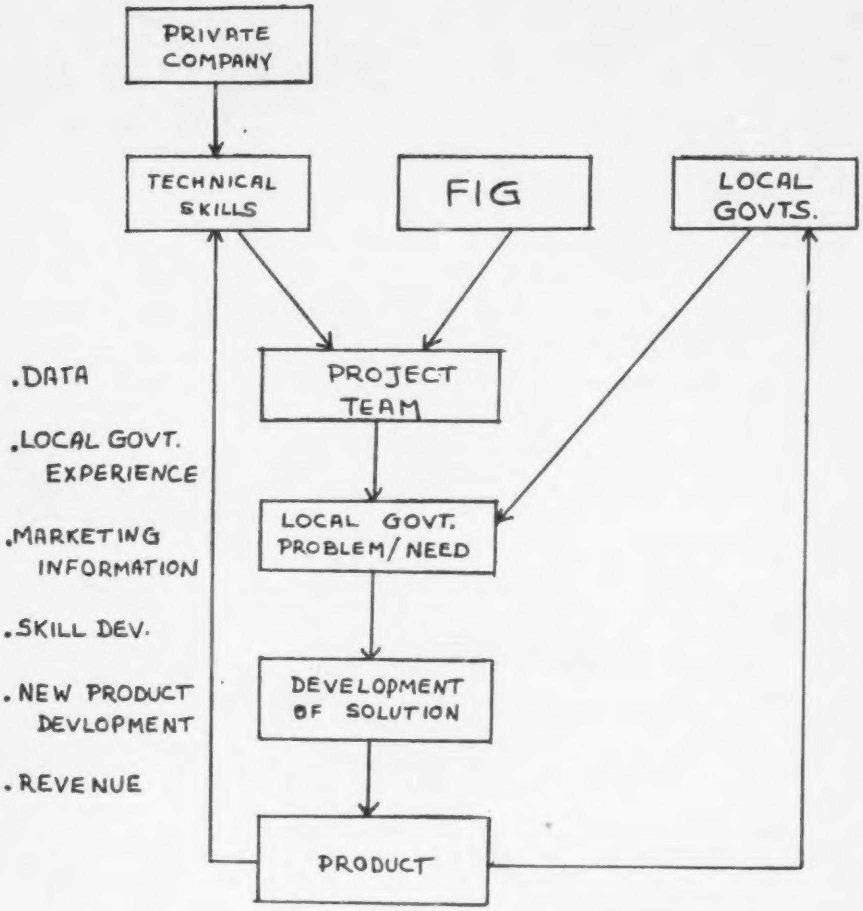
would then be tested in one or all of the financially participating jurisdictions. Once testing proves successful, the information would be disseminated through FIG's product awareness activities with local governments. As in model one, when FIG's product awareness activities create interest, such interest would then be supplied to the marketing people of the private company who would then follow up and execute sales. Upon the receipt of sales, royalties and if negotiated, a percentage of co-ownership in the product would be returned to FIG. FIG then could reimburse the initial participating jurisdictions so they could recover their cost of investment. Another option for the participating jurisdictions to recover cost investment could be the receipt of X number of products, once they're proven through testing, at no or heavily discounted cost.

The third model for private sector cooperation is entitled Soft Products/System Cooperative Program (Figure III). This model has evolved based upon FIG's experience with General Motors Corporation and the Urban Energy Assessment program in South Florida, as well as in California, Texas, Illinois, and New York.

This model recognizes that the private sector enjoys technical skills and product information and knowledge that may not be readily available within local government. It also recognizes that local government could gain from some type of formalized continuing interaction with large private industrial companies. In the General Motors program, General Motors' staff joined with that of FIG to create a project team. This project team then selected multi-jurisdictional groupings of cities and counties in five states to discuss how the technical skills of General Motors could assist these governments in the area of energy. Once energy needs were defined by the local governments, General Motors dedicated people, along with FIG, to develop methodologies by which local governments could begin to comprehensively understand the total energy picture of their total community. On the chart, this is identified as Development of Solution/Product/System. The final product of this process is returned directly to the participating local governments as well as to GM. In addition to the final product, the private company, using again the GM project as the example, gains additional benefit from such participation. In the GM program, the additional benefits were comprehensive sets of local government data on energy demand and consumption, experience in working with local government administrators and staff, detailed marketing information which is fed into GM for future product decisions, skill development in dealing with local government systems, ideas and concepts for future new product development, and revenue. In the GM program, each state grouping of jurisdictions directly pay General Motors $25,000. GM matched this by about five to one.

This type of activity is funded either jointly, as was the case in the GM program, corporately, or by a third party such as a foundation or the Federal government.

The above three models have been put together as a result of one year of experience on the part of FIG in dealing with small and large industrial


PRIVATE COMPANY
TECHNICAL SKILLS
FIG
LOCAL GOVTS.
PROJECT TEAM
LOCAL GOVT. PROBLEM/NEED
DEVELOPMENT OF SOLUTION
PRODUCT
.DATA
.LOCAL GOVT. EXPERIENCE
.MARKETING INFORMATION
.SKILL DEV.
.NEW PRODUCT DEVLOPMENT
.REVENUE

III. SOFT PRODUCT/SYSTEM COOPERATIVE PROGRAM companies. In the limited experience to date, each seems to be feasible for continuing implementation, but, several questions will continue to arise as we gain experience and implement these various options. For example, one continuing difficulty has been the interest of the companies to have exposure for their products beyond the State of Florida. This puts pressure on FIG to minimally provide product exposure within other states. Therefore, we're currently in discussions with the Southwest Innovation Group to provide a formalized linkage so we can provide such visibility in the Southwestern United States. The Florida Innovation Group's participation in NSF's National Innovation Network should ultimately solve this problem as other Innovation Groups recognize the need to work with the private sector.

Participation with the private sector is a major component of The Florida Innovation Group's future strategies, not only in terms of providing products to our local government participants, but also as a major financing component for FIG. We see these revenues, plus the dues from local governments, as the two major requirements for us to obtain independence from the NSF funding process.

Attachment B

Florida Innovation Group

Financial Structure

The Florida Innovation Group has several options which it could pursue in order to develop its funding base. These would include:

National Science Foundation Grants
Private Sector Contracts
Member Jurisdiction Dues
Special local R & D projects
Private Foundations
Technology Transfer Fees
Licensing Royalties
State Funding

National Science Foundation funding is intended to support The Florida Innovation Group during initial start-up efforts. As the program develops the National Science Foundation funds will represent a declining proportion of the total resources available to FIG with funding from various sources listed above gaining greater significance for continuing basic program support. It is anticipated that member jurisdiction fees will be relied on to a great extent. This will require a multi-year financial commitment from member jurisdictons.

NSF Grant

The NSF grant is intended for basic overhead, support staff, and a portion of management salaries. It is the intention of FIG that NSF funding represent a declining portion of the total FIG resources over the next five years; therefore, other sources of financial support must be developed to underwrite the FIG program.

In addition, it is FIG 's intention that member jurisdiction dues remain at a nominal level in anticipation of alternate sources of support. The destiny of FIG's program for Florida cities and counties should not be determined by the Federal budget process. While the Federal government should allocate reasonable resources to assist local governments in technology and innovation development such funds should supplement local financing. It is evident that there is sufficient imagination and ingenuity in Florida's local governments to generate sufficient resources to underwrite the technology program without significant NSF funds.

Member Jurisdiction Dues

The dues structure is designed to produce revenues sufficient to maintain anticipated FIG programs. Other revenue sources will enhance that program. FIG's target is to have 50 paying members by 1982 representing revenue of $150,000. As of now, we are half-way to this goal.

Research Grant/Contract Fees

Another source of FIG funding, although small at this time, is fees paid to FIG under contract to local government jurisdictions.

A contract between General Motors Corporation and Broward County and six cities in Broward County to conduct an Urban Energy Assessment program provides a small payment to FIG for its coordinating efforts.

A pending grant to Ft. Lauderdale to conduct a Pilot Study for Small Business Energy Management will provide a small payment to FIG for its coordinating efforts.

These type activities, as currently conceived, could continue to provide limited funds to FIG.

Private Foundation

Discussions with private foundations suggest funds for clearly defined research projects might be available from foundations. These funds would support special projects and would not be available to provide continuing support to FIG. The results of such research efforts, however, would be beneficial to local governments. Local government assistance in successfully approaching such Foundations is important if we hope to have any success.

State Funding

It is not anticipated that state funding will be available in the short-term to support FIG. However, in other states the state government does provide financial support. If this is a viable alternative in Florida a strategy for approaching Tallahassee needs to be developed.

Technology Transfer Fees

FIG will be conducting seminars and other means of encouraging transfer of technology from one jurisdiction to others. This could result in fees being paid to FIG from the using jurisdictions.

Such an effort is currently underway with the City of Anaheim, California. If other jurisdictions decide to purchase the Anaheim Fleet Maintenance Package a small fee will be returned to FIG. The purchaser will be able to secure a working program at minimal costs, compared to developing their own program, and FIG will receive a small fee to underwrite its efforts in making the technology available in this manner.

Such a concept could be extended to other appropriate technologies beyond Florida jurisdictions.

Licensing/Royalties with Small Businesses

An exciting possibility of funding for FIG is in the area of royalties from small businesses for the introduction of their technology into local government.

It is an established fact that the majority of new technologies are developed by private sector small firms. It is also apparent that many small businesses are not aware of the market potential in local government and have little knowledge of how to access or enter the local government market.

It seems reasonable that FIG might bridge that gap between small businesses and local government and receive compensation for its services.

For instance, FIG could identify new technology which seems to have potential application in local government and then develop product testing arrangements with local governments. Products which tested successfully in local governments would then have easier entry into the local government market. A contractual arrangement between FIG and the technology producer would return a royalty to FIG for all sales to local governments. In this manner local governments get the benefits of new technology, small businesses are able to enter a new marketplace with their products, and the FIG program is strengthened by the royalty fees.

Such arrangements between FIG and small businesses are currently in the discussion stages.

This could well develop as a significant source of support for FIG in the long run.

Mr. WALGREN. Dr. Baumann.

STATEMENT OF DR. DWIGHT M. BAUMANN, DIRECTOR OF THE CENTER FOR ENTREPRENEURIAL DEVELOPMENT, AND PROFESSOR OF ENGINEERING DESIGN AT CARNEGIE-MELLON UNIVERSITY

Dr. BAUMANN. Thank you for this opportunity.

I recently was involved in organizing a conference for deans of business schools and deans of engineering and your college, Congressman Brown, was one of the most thoughtful and provocative speakers at the entire conference; thus I am sure your committee does not need to know very much about innovation, engineering, or technology. I have always stayed at the universities because I thought it was the place where one could call a spade, a spade and where "One would rather be right than be President," and a few other definitions of that kind. Then I heard Milton Friedman say that true academic freedom only existed if you were a tenured full professor at a private university within 1 year of retirement.

I am not quite up to that point, so I may be stepping on some dangerous ground at this point, but I would like to just quickly summarize a few issues.

First of all, Dr. Branscomb this afternoon gave a very strong statement about engineering predominating over science in providing the technology that took us to the Moon and other technological achievements. I think that is very complementary to what I heard Congressman Brown say as well, but Branscomb didn't then describe how the Board's reorganization of the National Science Foundation reflected that.

In my estimation, applied science is engineering. So diffusing applied science into all of the other sciences does not solve a particular problem. I think the Science Board might have been intending to make the distinction go away, so that this committee would not have to continue to harangue with the National Science Foundation over what is technology and from whence comes innovation.

I suggest furthermore that perhaps the reason the Board made these changes in absorbing applied science into each of the divisions, was not Dr. Slaughter's doing, as I understand it. I studied very carefully where it comes from. I think the Board did this to make sure that the engineering directorate was only one-seventh of the proportion of the National Science Foundation, no matter what the portion of the budget for applied sciences. Thus it would indicate that only one-seventh of the Board members would come from engineering. I believe furthermore, that the engineering or applied science portion should be at least half, by the way, because I think, as Billy Carter might have said: "There is more of us than there is of them." There are more engineers and I think they are more involved with making sure the "baby stays in the dishpan instead of being tossed out with the water" as I perceive some of the NSF's present budget cuts to be doing.

I would also like to deal with the budget cuts. I don't think they are as ominous an omen of a misunderstanding of the role of technology by the new administration as they appear. In my quick look through the Carter budget, and that is all I had a copy of, it seems to me the parts of the budget that are now cut out were the ones that looked as though they might be available to the industrial private sector and the budget cutters were simply looking for something to take away from everybody as they had taken it away from everybody else and were now taking something away from the private sector and those are the ones that got X'd out.

I am not sure that the new administration has gotten to making a science and technology policy yet. I expect the present administration to be more interested in innovation rather than less.

The next point. Let's quit kidding ourselves about what is going on in graduate schools of engineering. More than one-third of our Ph. D. students are foreign nationals. Many of them are here paying less tuition than out-of-State students do at many State schools. Only two-thirds are Americans. I would recommend, and have in my testimony recommended a committee be called, an appropriate joint activity between this committee and whoever is involved in foreign affairs, to deal with the question of paying for foreign students' participation up front as part of our foreign aid policy. This would be of tremendous assistance to higher education and would make a more honest "National Science Policy." I'm not sure that the National Science Foundation should be supporting the amount of foreign development as it does via producing technologists that could, even if they now don't tend to, return.

The Nobel Laureate, Ted Shultz, points out our own successful foreign aid program has been education. It is an axiom as old as mankind itself, "You give a man a fish and feed him for a day, you teach him how to fish and you feed him for life."

It is about time that the Congress suggested to the State Department's foreign development arm, Appropriate Technology International, Inc., that they get involved with foreign nationals who are on our campuses and who might take technology back to their country to produce industry there. I have tried to address this within ATI, and I find my comments falling on deaf ears, but someone has to ask that question and that is the way I think it should be handled.

Let's look at the other point that has been brought up: Our graduate school enrollment is down. If we are making a product and we find out that the deluxe model does not sell but everybody is buying the stripped-down version, we normally think: Well, these are bad economic times. And they really can't buy the deluxe product, so they buy a stripped down version. But it turns out they are buying the stripped down version for a higher price than the deluxe product costs.

One of my brightest bachelor students just turned down a $32,000-a-year job and there are only three professors at Carnegie-Mellon who make that much money, so we are building a product, our deluxe model, and it is not appreciated by anybody but foreign students, (most graduate schools of science and engineering could fill their classes with foreign students, if they had the funds), and a few Americans.

I think the real issue is, that we have designed our graduate student product to match specialities that are no longer of interest. This industry would prefer to generally accept the bachelors level and they prefer to train them in their own speciality, because they are tired of the esoteric manipulation of science, as Congressman Brown put it, "Where 'pure' is defined as being as far away as possible from reality."

They are tired of the mathematical manipulation being defined as science because most engineering science is not theory, it is not the development of new theory, it is not science, in the sense of scientific discovery; but rather, it is simply mathematical modeling and while it is a good skill to learn and it is a good skill to teach; one should not call it "pure science." Most professional engineers apply science because of a developed intuition and creativity that deals with "ingenuity" from the root word for engineer. They use models and mathematics to optimize the process after they have defined it. The process is interactive, but we must remember that there is a skill and judgement component, as well as a modeling component.

I think we have to start to deal with the problem of inappropriate education in engineering for what it is. The education directorate of the National Science Foundation has been singled out for not doing its job and I think that is correct, because they didn't help prepare engineering colleges to turn from their aerospace and science ways to the industrial ways that industry now needs. I don't think what one does now, however, is to burn down the barn or close up the education directorate, but one plows it down and lets it grow again.

I think our problem is that we have not converted our tenured faculty members from being esoteric science-like eunuchs, and that is a strong word, I don't want to make it quite that strong, into being useful engineers, and engineering role models, that our industrial society would like to see.

The budget cutters have also apparently cut back the social sciences. Clearly more social science is needed. The question that Congressman Weber asked about the Japanese should have been answered by observing the difference between a Japanese student's view of learning, not by the difference between some kind of grant in global national policy.

Some years ago, while still teaching at MIT, I had a Japanese student come to me with a list of courses he wanted to take and things he wanted to learn in the library. He said he came because he read some of my papers and wanted to work with me and made an agreement with his company to do this. His company was a company that had given him tenure after working there 3 years and he knew he had a lifetime job. And his list was an interesting one and this student was very bright.

In his second year, and as he had done all of the things he needed to do, I looked over the list and said, "By the way, if you took just this one course in math, you would fulfill all of the requirements for a master's degree in mechanical engineering at MIT."

He said, "That would take my time away from the library."

I said, "Well, the math course would be simple for you."

He said, "Professor Baumann, you don't understand. I don't need a master's degree from MIT. I made a deal with Toshiba and that was to learn these things for the company."

Now, we call that a fancy name, as "Human Resource Accounting," but they have learned how to implement it.

Finally, I think that we have been missing in terms of development of high-level or highly trained or advanced over the baccalaureate degree people. We have forgotten how to teach them, in the sense of helping them learn to be creative, because most of our faculty does not know how. There is and always has been very great pressure on the excellent practitioners and artists of engineering to leave the university and go to industry. This is especially true now. Thus the present faculties have forgotten how to teach in the sense of helping students to be creative, or have forgotten how to have them address problems for which there is no textbook solution. Dealing with, in the sense of teaching, the "art" of engineering is a labor intensive and cost intensive activitiy.

In my estimation, what needs to be done at the graduate level in engineering, to produce real engineers as opposed to the fodder for management schools, law schools, and other professions, is as close to the art of medicine being taught in the teaching hospital as any other analogy I can think of. We need to find ways to take a few people who are qualified to become the people who make things happen and to set them aside and prepare them for a lifetime job of innovation. It won't take very many. I suspect now we ruin more in a week than the Nation could stand if they all were put to work productively.

My thesis starts with the idea that our society, America, is replicated or thought it was replicating the Edisons when we invented the engineering school because those were the national heroes. When we discovered that these engineers were not quite up to snuff, we invented a "Band-Aid" called MBA and stuck it over some of them. But it missed the point and the point is that Tom Edison and Henry Ford and the others were innovators in many dimensions, they not only understood products, they understood customers, they understood finance, they understood how to get people to work with them. They were innovators and inventive people in many dimensions.

I think it is possible to recover and to have some of what was desired occur, if what we continue to develop has some studios where there are creative and innovative people to teach, to be examples, to criticize, to learn, and an environment such as the one I believe we have been somewhat successful in putting together at the innovation center at Carnegie-Mellon University in Pittsburgh.

The numbers are in here [pointing to his prepared testimony]. You can argue with the numbers; but there are also many more companies we worked with than the ones who are reported here. In many cases the help given, was simple assistance over the telephone; but crucial and critical questions were answered that helped entrepreneurs to survive and become successful.

For about 10 years we have been involved in an experiment which was essentially to develop the concept of a revolving fund for out-of-pocket startup costs. There are a great number of people in this country today who have every confidence and ability and drive that is needed to be innovators, to be employers of people, and the only thing they lack is credibility. Thus, we have tried to help add credibility to their package.

With a half a million dollars, which is what the fund had in it for the NSF sponsored portion of the experiment, the other half was overhead; we have been involved with these 16 companies. Some of them are still embryonic at this point; they are in gestation. At this point we can account for about $17 million a year of sales in Pittsburgh. We have attracted $14 million worth of outside capital in Pittsburgh. We have something on the order of 380 jobs.

If you calculate the payroll as being roughly half of sales, as it is in many of these kinds of industries, and if you calculate the people, even the low brackets pay 10 to 20 percent taxes, you find this experiment and research project in innovation policy, is paying back to the Government about $800,000 a year at a 10-percent tax rate. That is for an investment of $1 million over 5 years.

Now, this was an experiment and thus it had a lot of experimental aspects that may not be the most efficient. I don't think it is anywhere near what one can do if one is setting out to teach engineers in the sense of ingenuity, or in the sense of the French word for engineer which really meant one with native intelligence and to put them to work as our society intended them to work, as people who brought technology, science, to the usefulness of mankind. If we could accomplish this then I think we would discover a new awakening and we would discover that American students would find the value added of coming into a program like this is worth the cost. In the same sense as the teaching hospital, produces both experienced practitioners, and research results; while in part paying its own way in terms of direct service to society—the innovation centers can also accomplish a similar task.

In my estimation, the programs in the National Science Foundation that have been dealing with experimentation in public policy and experimentation in educational systems are the ones to which we should pay more attention, not less.

Thank you.

[The prepared statement of Dr. Baumann follows:]

Before the House Subcommittee on Science Research and Technology

HEARING ON
APPLIED SCIENCE, ENGINEERING AND INNOVATION

Thursday, March 5, 1981
Rayburn House Office Building--Room 2325

Text of Testimony on Applied Science, Engineering and Engineering Education

By Professor Dwight M. Baumann, Director of the Center for Entrepreneurial Development and Professor of Engineering Design at Carnegie-Mellon University in Pittsburgh Pa.

Introduction

The National Science Foundation has been a mainstay in the development of science and technology at our colleges and universities. The major impact of the NSF's policies have been in the role of providing grants for graduate student and faculty research, equipment grants and the support of educational experiments. I shall discuss these roles of the NSF from several points of view and from the perspective as an educator, with considerable contact with industry and as an engineer with a vital interest in innovation and innovation policy. I have had a career-long interest in changing the directions of education toward greater potential impact on industrial innovation.

In order to place my comments in perspective, let me introduce myself. I was born in North Dakota, raised on a small farm and graduated from North Dakota State Agricultural College. I attended MIT on scholarship and research support, and obtained my M.S. and Sc.D in Mechanical Engineering. I was then on the faculty at MIT for eight years and am now a Professor of Engineering Design at Carnegie-Mellon University. I have been involved in the startup of numerous businesses in Boston and Pittsburgh. I have just recently been the Vice President for Public Affairs of the American Society for Engineering Education, and am presently completing the proceedings of the National Conference for Deans of Engineering and of Business, which I organized as a continuation of the 1979 Domestic Policy Review of the White House. I might add that the conference took place on December 1,2,& 3, 1980, in St Louis Mo. and was attended by some 200 educators, all of whom were greatly concerned with the present role of higher education in innovation. I am an inventor and am presently involved in the reorganization and revitalization of the National Inventors Council. I have been a consultant to many large and small businesses; I have been on the board of both large and small businesses; and have several times been a CEO with direct payroll and profit responsibility. I have served on the Governors Economic Advisory Council of the State of Pennsylvania, the Economic Development Committee of the Pittsburgh Chamber of Commerce, and was a U.S. delegate to an East-West Conference on Industrial Innovation held in recently in Vienna, Austria.

I would like to address some of the areas of my concern with the present newspaper discussions about the budget of the Foundation, because I believe there is a great deal of public misinformation about the role of science and engineering/applied science in our society today. I would also like to tell you of some of the results of an experiment in public innovation policy that has been funded by the Foundation at Carnegie-Mellon University in Pittsburgh during the period 1973-78. Most importantly I would like to present this Committee with some views of appropriate directions of research that should have a significant potential for reversing the U.S.'s pending technological stagnation and, I believe, would be possible to rekindle some of what was formerly called, "Yankee Ingenuity", that for many decades fostered the "American Way of Life".

First, let me state that I also believe, as others have pointed out, that we have been dwelling on income redistribution for so long that we have lost track of the process and function of income creation. The encouragement of commerce is just as much a part of our constitutional heritage as the provision of various protections and rights. For a long time our rates of economic growth, due to discovery and development of new products and new markets, gave us the high living standards that attracted the world to our continent. The so called energy crisis alone has not created the economic slump we now find ourselves in. Other countries with little or no domestic energy supplies have been able to fare well in the world marketplaces in spite of their lack. I believe we have come to the place where the lack is not of resources, or capability, but lack of motivation and resolve.

Furthermore that lack of motivation is fed by the inappropriateness of some of the role models, and activities at many of our institutions of higher education. The heavy involvement of Federal support for science and technology, which is necessary, has created a system of education and research that is not appropriate to our present needs. The country can ill afford to have the system continue in its present direction. The answer is not to retreat to having the government only support so-called, "basic science" and expect someone else--the private sector, to support "applied science." Unfortunately, the alternative of allowing the system of higher education to proceed in its present direction and, as a consequence, simply face economic collapse is also not an acceptable solution because the cost of rebuilding the system must also ultimately be borne by society, and the loss during the interim is unacceptable.

I believe that the engineering school is itself an American invention. RPI was the first school of Civil Engineering as contrasted to the Military Engineering programs that began in Europe. America fostered the concept of Engineering Education during the turn of the Century and then again more recently because it understood the engineering activities of men like Henry Ford, Tom Edison, George Westinghouse, George Eastman, Harvey Firestone, Eli Whitney, and many others. The heroes of the turn of the Century were the engineer--entrepreneurs. It has been said that during his lifetime, Thomas Edison was the best known person on earth. During the period after WW-II, our society became aware that the engineers alone were not adequately prepared in some areas of economics, finance and marketing and so America embraced the idea of a business education. Even though there were some few ivy league schools of business, the major growth of the MBA was after the 1950's.

The fact is that, at present, (1981) schools of engineering are facing some of the, all-time, heaviest demands for their services at the undergraduate levels, and at the same time some of the lightest demands for graduate education of American students. The present engineering and science educational system at the graduate level is as heavily dependent on foreign export as is the agricultural surplus. On the order of one-third of our graduate students in the 250 accredited schools of engineering are foreign nationals. Needless to say, a college education is perhaps one of the few service industries that is exportable. The ultimate international benefit of the massive education of foreign nationals is itself a major foreign aid function--perhaps it should be funded through the budget of the State Department. (Nobel Laureate Ted Schultz points out that education has been the only successful portion of our foreign aid package.)

> I should like to suggest that this committee conduct hearings, with whatever appropriate committee that is involved with foreign aid, and discuss the mechanisms for supporting the costs of graduate education for foreign nationals as a part of our foreign commitments, rather than our continuing the charades between the engineering faculties and the taxpayers over who needs to do what for whom.

Nevertheless, the massive education of foreign nationals is, and should be, producing the seeds that have the potential of increasing the standards of living around the world without reducing our own. Thus the practice of providing an American education as an export item must be continued. I believe there is adequate evidence that it should be enlarged. We should quit taking the short term view for which both industry and politicians blame each other, and consider the well known old saying, which actually stems from an old Chinese proverb:

> If you give a man a fish you feed him for a day. if you teach a man to fish you feed him for life.

How can our nation be the last to understand the maxims, motivators, and enterprise principles that were part and parcel of our own success? I, for one, do not believe that there is an insurmountable problem associated with the world depletion of natural resources because of the fact that there are many technological substitutes plus recycling potentials for most, if not all, of the so-called critical items. I don't believe we will run out of resources before we run out of tolerance. Exporting our most successful product, education, should have many more long range benefits than any alternative.

Renewing Innovation Skills--Regulation is NOT the Problem

There are many who would say that the problems facing innovators and industrialists in the U.S. today are caused by over-regulation by the government. This is possible, but I believe that the regulations in many cases create as many opportunities as they foreclose. Many small businesses have developed around the concepts of helping other industries comply with regulations. If one includes the legal profession and the private consultants it is probably true that there has been an increase of business due to regulation. I have been a student of the regulated transportation industry, and it is clear in many cases that it is to the advantage of many industries for there to be regulations, especially if is required uniformly of all competing suppliers, and, if it is possible, to pass the costs on to the customers. This covers the insurance industries, the banking industries, manufacturing, and many others besides the transportation industry. One can almost say without too much exaggeration that regulation is: for technocrats, bureaucrats, lawyers, planners, consultants, etc., what the WPA was for laborers. There may be a significant difference in the case of regulators, however in that the "public works" aspect and the compliance requirements are usually high skill level jobs--above the entry level--and thus the jobs produced may have more secondary job production.

Definitions--Things are not What They Seem

Engineering-The Application of Science

The major activity of engineers in the United States is the application of science to the complex needs of our society. There is considerable misinformation about the specific role of the engineer vis-a-vis the scientist. This is perhaps due to the popular press' interpretation of the role of engineering. Indeed it may be in part due to the misstatements of engineers themselves in describing their activities.

When the National Science Foundation was formed there was considerable debate about whether it should include the words, "engineering or applied science" in the title of the new agency. In the biography of Vannevar Bush, the first Science Advisor to the President, the early events are described. In fact the title for the Foundation chosen at that time reflected not only the American but the British views of the word science. Remember these were times when there was considerable insecurity among the greatly expanded engineering profession. Much of this insecurity came from the fact that one major engineering activity (putting science to work on applied problems), the Radiation Laboratory at MIT during WW-II, quickly discovered that the electrical engineers of that day did not have sufficient background in high frequency electronics to solve some of the application problems of radar. The later space activities and the national concern with a post Sputnik buildup of a specific technological capability created even greater aberration of the word engineer because the media, the public, and thus the congress began to use the term science to mean the most generic sense of the concepts of both science and technology. Needless to say there are yet those engineers, primarily of the generation that is now over 50 years of age who still prefer to be called scientists because they believe that it is somehow a higher calling.

> Frankly, at this point, I have not been able to understand the purposes or the intent of the reorganization of the National Science Foundation to set up Engineering as a separate directorate and to merge applied sciences with each of the other directorates.

I have re-read the first speech given by the new director of the Foundation at the National Conference for Deans, which I organized. I realize that the die was cast by the National Science Board before he assumed office. From his address to the conference it is clear that Dr. Slaughter understands the semantical difficulties. In his words:

> "Let me talk a little about the semantics, especially the often artificial and forced distinction between "basic" and "applied" research. A particular research project may be characterized by many attributes -- for example:
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> - the motivation of the researcher;
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> - the motivation of the sponsor;
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> - the strategy of step-by-step decision making in the conduct of the research; and,

- the ultimate way in which the results are used, including the time horizon for probable utilization.

This highlights the differences in perspective and expectations of accountability among those who do research, those who select projects for funding, those ultimately responsible for raising the funds, and those who hope to apply research results in useful ways.

From my current perspective at the Foundation, and that of a former researcher and university administrator as well, I believe that virtually all research is potentially applicable."

"When one begins rethinking the distinctions between basic and applied research, it becomes apparent that some of the hard and fast lines we have been accustomed to draw between science and the frontiers of engineering, also begin to look pretty fuzzy. Although engineering was born as a practical and intuitive art, today it embraces a range of knowledge from the highly theoretical to the very practical. Engineering builds linkages with physical, social and life sciences on one side, and with industrial practices on the other. Those engineers who devote their lives to creating the engineering of the future are as concerned with the discovery of new knowledge as with the application of knowledge already attained. For this reason, it is wrong to think of engineering research as applied research or vice versa."

"I believe we should look on the totality of research as a fabric made of many different-colored strands--one color for pure mathematics, another for ceramic materials research, and so on. What we see then is a seamless web in which the strands intertwine and intersect but also can be distinguished if need be. This whole fabric represents the process of scientific inquiry, with practical applications stimulating and reinforcing research and vice versa.

Let me now turn to how the Foundation organizes itself to support research ranging from cellular biology to the design of buildings that can withstand earthquakes. The Foundation's structure reflects the fact that it has statutory mandates to support basic research and education in all the sciences and in engineering, and also to investigate the application of scientific and engineering knowledge in the service of national needs. The challenge to the Foundation is to create a structure that is flexible enough to accommodate creativity in both the search for new knowledge and the seizing of exciting and useful technical opportunities. This is not something we expect to do via the mere shifting of organizational boxes or reallocation of dollars. It involves a subtle but fundamentally significant broadening of perspective on the part of those throughout the science and engineering communities who have been accustomed to thinking in terms of science versus engineering or basic versus applied research. This objective is not a novel one for the Foundation. We believe we have already achieved it to some degree in the management of some of our programs--for example, in our Division of Materials Research. But, we intend to go farther.

As a step toward meeting this challenge, the Foundation has just announced its intention to establish a directorate for engineering, and to change its method of managing applied research. These changes, I believe, will make the Foundation's structure more agile and allow for a greater degree of mutual reinforcement among the various strands in the research fabric.

We are going to make the support of applied research an explicit responsibility of all our research directorates. Currently, our Engineering and Applied Sciences directorate has the sole responsibility for applied work. Under the new arrangement, the directorate for Engineering will join the directorates for Astronomical, Atmospheric, Earth, and Ocean Sciences; Mathematical and Physical Sciences; and Biological,

> Behavioral, and Social Sciences in carrying out both applications-oriented and basic research. This will broaden our base of support for applied research and give new emphasis to our support of engineering research.
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> We intend to work out practical arrangements for ensuring that the selection and review processes in all directorates pay close attention to the full fabric of research, and that we also have the means for identifying the threads for reporting and management purposes.
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> Again, I want to emphasize that the nature of this reorganization reflects a subtle, yet significant shift in the way we plan for and allocate our resources rather than specific immediate decisions on dollar amounts or proposed allocation of those resources. But a look at the evolution of the Foundation's budget for engineering in recent years may be of interest.
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> The Foundation has traditionally devoted the bulk of its resources to basic research. The House Science and Technology Committee recently reaffirmed that these core research programs "must be maintained as part of the Nation's effort to maintain world technological leadership and (to) protect national security."
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> At the same time it has been expanding basic science programs, The Foundation has been developing and expanding its support for engineering. To cite just a few statistics:
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> - Between 1972 and the current budget year our obligations to engineering grew nearly two and a half times, to a level just over $61 million, while the total Foundation budget grew by less than a factor of two.
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> - About 16% of our graduate fellowships and nearly half of our university-industry cooperative research grants go to engineering schools.
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> - In fiscal year 1979, we provided $78 million, or nearly 30% of the entire Federal government's obligations for engineering research performed at our universities and colleges. We provided more than 40% of total Federal support for basic engineering research in universities and colleges."

Dr. Slaughter's comments commendably describe the reorganization and its intended purposes. I believe Dr. Slaughter's comments must be put into context. His speech was intended for academics. He was including those over 50 who insist they are scientists working on pure research. My purpose of this brief description is to deal with the semantics of those aspects of the support of science and technology that need to be nurtured by the government and to discuss the expected return our society can expect to receive from the public support of technology.

Let us also mention, but only in passing the old saw, that throughout the aerospace era the successes were said to be "successes of science, but failures were said to be failures of engineering." In the instant case of the legislation to implement the national needs for Federal support of Science and Technology, we perhaps need to define by more specific task, some of the needs of the field of engineering today in the 1980's. The term "science" alone is simply too broad to be useful in describing the present needs of our nation in terms of public support as differentiated from the self interested, private support of science, technology and the education of the scientists and technologists that is needed by our country for economic recovery and the maintenance of a high standard of technological existence.

The term science, alone spans the scale from the general "Science is Fun" view that makes good television to the problems of helping the recovery of the shoe and textile industries. It unfortunately includes the, "just give me the money and leave me alone" aspect that I have alluded to before, to the help us get started with a better relationship between industry and the university so that we can learn to support applied science ourselves. The question of scale, time horizon, and many other issues are too interwoven for the debate to take place in this forum. Our best approach, then is to assure that the best, well intentioned minds, control the details of the organization of science and technological support. The choice of Dr. Slaughter, an engineer and a scientist as the Director of the NSF is a move in the right direction. The next and most important correction will be to increase the Engineering and specifically the more design and applied engineering oriented membership on the National Science Board. When that happens we may see results from the Congressional inputs of this Committee's suggestions for increased effect on innovation and engineering applications, without the obfuscation of reorganization. Absent more significant moves by the Foundation in the direction of Engineering I would strongly recommend the development of the National Technology Foundation that this Committee has been working on. I believe that there is strong support from the Engineering Education community for a National Technology Foundation.

Basic Science vs. Applied Science

A second common misconception in the popular literature and a common abuse of the language is the loose use of the terms basic and applied science. Professor Clarence Zener of Carnegie-Mellon University, himself a respected scientist and Engineer, a member of both the National Academy of Science and of Engineering, says, "There really should not be a distinction made between basic and applied science." He then goes on to point out that everyone begins to solve an applied science problem. It must be an applied problem because everyone needs to justify working on the problem to someone, if only to one's self. A person needs to be well prepared and working on a defined problem to be in a position to make a so-called discovery or breakthrough. It is only if the discovery has general usefulness, aside from the problem the scientist was working on, that it begins to have the attribute of being, "basic." Zener, an honest and humble man thus makes the point that basic is so often misused by people to describe their own work, when it should only really be allowed to be used by others to describe work of most general usefulness.

The confusion between basic and applied science, has led to a great many false concepts and impressions about science. True there have been accidental discoveries in science, but these have also been both rare and occurred to practitioners who were well prepared and active in seeking for the answers to a specific problem. The examples of discovery of electricity from the chance observation of the kicking of a frogs legs and the discovery of penicillin from the accident of mold growing on a Petri dish are really very few and far between. In fact their rarity is exemplified by the many years between the accidents that are described in the litany of science. The repetition of these examples may in fact be more related to the hope of all creative persons, and scientists are no exception, that people will just let them be creative and not bother them with questions about, "what are they doing now?" The correct answer usually is, they are thinking about ideas that are too difficult to verbalize without being distracted.

The basic point of this discussion has been that the terms "basic and applied" are commonly used prejudicially and involve the eqo of science. Who would want to believe that there were still basic discoveries to be made on some of mundane artifacts of life, like the reason a bee can fly. I suspect that just as the legislation regarding the DOD research justification requirements produced apologetics, the suggestion by congress that more of the work be applied, would cause a great many proposals to be rewritten to show the applications. Conversely a perceived move toward funding more basic work will produce the arguments required. Creative people express their talents in many ways. I suspect that:

> The reorganization of the engineering directorate of the National Science Foundation by the National Science Board had more to do with the concern of the board that the congress was intent on giving more specific instructions to the NSF on what it wanted accomplished than on any other reason. Furthermore the threat that a new National Technology Foundation be formed may have had a significant impact on the same decision. If we are to accept the definition that the Technology Foundation would deal with applied science, then diffusing technology throughout the Science Foundation would make it more difficult to form the National Technology Foundation by splitting up the National Science Foundation.

In the area of the Federal funding of science and technology there has been considerable interaction between the needs of the bureaucracy for exposure and a constituency and the political realities of the needs of the electorate and the elected to appear to understand what is happening. In the case of the National Science Foundation, we may never know how much effect there has been on science policy and on the misnomers applied to scientific problem solving caused by the singling out of specific grants for ridicule based on the oversimplified titles of the research.

The Case of Specialization in the Engineering Profession

The engineer, as the person who applies science to the use of mankind, is a professional in the same manner as the Doctor or Lawyer. The many fields of engineering require specialization just as do the other professions. During the past three decades the activities that attracted the attention of a large number of new engineering graduates was often connected to our efforts in space and so called "high technology." Actually; the term high-technology simply means the newest technology, or the area of technology that is obtaining the greatest degree of attention, often by means of direct government subsidy at the moment. Needless to say, we thus have an entire educational establishment of tenured professors whose primary expertise is in a very narrow field of engineering. It is agreed that the so called "basic engineering sciences" do in fact have a general applicability to most of the foreseeable fields of engineering, and in fact they are self defined as being those areas of mathematically analyzable problems of technology that lend themselves to simple expository teaching. Some wags describe this as "the lecture--passing from the notes of the professor to the notes of the student without passing through the mind of either."

This engineering science base is part of each accredited engineering curriculum in the over 200 baccalaureate engineering colleges in the U.S.. However the requirements for accreditation include activities in the practice of engineering, often called design, that by requirement of the profession must cover at least one-eight of the program during a four year degree. On top of this applied portion of the engineering curriculum, there is an additional requirement that the basic, "engineering science" courses have adequate laboratory activities to demonstrate the theoretical concepts and to help to develop the engineering intuition of the students.

It is widely understood that this applied, as contrasted to theoretical, engineering education is needed because very often the development of engineering concepts all the way to the production stage, takes place long before they are adequately understood to be described and optimized mathematically. For example, after all these years the turbulent flow in the combustion chamber in automobile engines is still not described in terms that allow a mathematical optimization that is anywhere near the results that have been and are obtained experimentally by cut-and-try techniques. If engineers have to wait for the development of the basic sciences before practical devices could be produced, this world would have very few of the machines and technologies that we enjoy today.

Specialties are Developed by Practice

The point of this discussion is that the laboratory experiences and the design activities in the engineering curriculum are expected to provide the learning experiences necessary for producing the engineers who can solve our specific industrial problems. To have misplaced the efforts in this area of education which, for the bachelors level of engineering education, takes on the order of one-fourth to one-third of the educational program, would be equivalent to teaching all the doctors to only do appendectomies, or all the lawyers to only practice probate law.

There are those who claim that the practical education and the learning of the art of engineering could and does take place within the industries that employ our engineers. Often the company that pays for the training in this mode is not rewarded by the fruits of its investment because the engineers leave to go into other pursuits. Furthermore, the industrial environment cannot pay primary attention to the needs of the student, but rather needs to be concerned with the immediate success of the project. Aren't these areas of endeavor where the collective nature of the benefit to society from education properly paid for collectively, or individually by the direct recipient, either through loans or direct taxation due to enhanced earning capability of the educated person.

The question of education as a personal or a "public good" is an age old one. Asking that industry, somehow pay for the applied research in universities when it is already paying the salaries of the professionals produced by the universities seems difficult if there is no mechanism for the specific industry to uniquely harvest the specific new knowledge which it paid for in sponsoring research. Education and research are mutual byproducts in most graduate programs in science and engineering. The longstanding policies of universities regarding openness of ideas stem from the ancient discovery that general dissemination of knowledge and the exclusive dissemination of knowledge are incompatible.

Other Market Demands for Engineers

Management, sales, and many other professions, even law, medicine, and government have found that the analytic skills of the trained engineer make them attractive to other professions than the ones for which they are trained. Certainly if they are in part mistrained for direct employment without applications experience this mismatch enhances their decision to leave the engineering field. In these cases, society perhaps still gains but the basic efficiency of the process of developing engineers is not optimum. If the practical skills developed in the classroom do not directly lead the students into civilian, industrial engineering jobs, for whatever reason, then they are more easily attracted away from engineering. Even though we are thus training an unprecedented number of engineers at the undergraduate level, there is evidence that numerous industries have had to bid very high to attract new graduates into their companies.

A second part of this analysis is the fact that the same industries are not paying an adequate increment for the benefit of a graduate education. Herein lines the conflict. By and large students pay to obtain an undergraduate education in engineering but are paid (even though a small stipend), to obtain an advanced degree in engineering. The only exception of which I am aware is the twenty to thirty master of engineering candidates in engineering design that are attracted to Stanford University each year without stipend or tuition scholarship. What is happening here thus is that the major faculties of engineering are so interested in doing research and teaching of graduate students that they will find ways to gain research support to do so. There is of course salary pressure put on the faculties at many universities by their administrations for many reasons. Research increases visibility, overhead helps cover inflation costs, outside sponsorship allows a faculty to be larger and have more diversity on a fixed E&GO budget, etc.

If we consider the present plight of graduate education in the U.S. we find the greatest aberration in the present production of our most important national commodity, trained professionals. The graduate programs in most of the engineering colleges in the U.S. depend greatly on the support of research and development projects conducted by the faculties to provide for jobs and research assistantships that support the graduate students in the pursuit of advanced degrees. It is these faculty's activities, their means of financial support and the equipment available to them, that sets the specialties for which professional engineers can be educated and trained. The analogy to the medical profession is perhaps most appropriate here. The MD's have only two models to deal with, male and female. The engineering profession ranges much more widely and often the mistakes of the engineer are even more serious and cost more lives than the mistakes of the MD's.

The distorted salaries at the bachelors level, along with the general realization that there is presently great potential for unemployment in many areas of our society, creates an environment where many students opt for the short run of a high paying job now that may have a plateau, a phenomenon long observed, in their earning abilities at a later date.

Is the Marketplace Telling Us?

In the related phenomenon, industries are not bidding as high for engineers with advanced education at the masters degree level as the students perceive to be necessary for the time lost in promotions and salary increases and thus there is less demand from students for advanced degrees. This apparent lack, needs very careful analysis. It is particularly important because the present aberration of the market phenomenon has considerable long term consequences in our society. By the very nature of our universities, they are conservers of values and practices in many ways. The faculties are chosen for specialies that are trendy in that each of the universities wants to be attractive to the demands of society at the time of hiring new staff. However after the universities have made their commitment, like many if not most large corporations and government, the universities make life-time commitments to "tenure" these faculty members, thus defining the specialities that will be taught, absent retraining of faculties, for some thirty years.

At the graduate level the marketplace may be telling us that the present product--graduate trained engineers are not sufficiently attractive to pay the marginal price. This may mean that the industries have become resigned to the fact that they will have to do the training--on the job. Another hypothesis is that the present focus on the analytic skills in some of the engineering sciences that are so prevalent in graduate programs in engineering are not appreciated by civilian industry.

At the undergraduate level of education the basic thrust is in the production of the engineering generalist. Graduate education usually produces, a more specialized product. The possibility exists then that the demand is for generalists rather than specialists, and specifically not for specialists trained in the wrong specialties. This need for generalists, if true, suggests the need for more social sciences and more people oriented skills. The political and regulatory environments at present would suggest the need for broadening rather than narrowing of the engineer. No amount of reduction of the rate of increase of governmental regulation will make a step change in the need for compliance with regulation. Other countries are caught up in some of the same regulation and the trend will be impossible to reverse.

The faculties in many of the foremost universities may be versatile enough to change some of their activities to meet the market demands for support of their research. This is certainly not the case for the majority of institutions. These few bellwether institutions are significant because they set many of the trends of education. In the past, the National Science Foundations programs have been very important in setting some of the educational policies at the graduate levels in the engineering colleges of our country, to the degree that there has been a bias in the type of support of engineering from government. From NASA, DOD, DOT, DOE, as well as NSF, there has been a large impact on the probable misdirection of engineering by the government, as it is now perceived by the lack of appreciation by the marketplace of the activities of engineering colleges in the U.S. It is difficult to take the position that the mission agencies of government should change to the support of fields of endeavor that would set the tone of engineering colleges toward the industrial sectors, thus it remains for the National Science Foundation to offset the bias produced by NASA and DOD on the directions of engineering education. In the same manner that society saw fit to marshall its technical and scientific forces in the race for space, it must now understand that some of the cost of doing the job of an all out effort to reach the moon is the cost of reconverting the systems, including the educational system back into producing the necessities of an international society in the throws of economic warfare that can only reduce our standard of living unless we find renewed methods of applying ingenuity to the problems of society. In hindsight this ingenuity is what we call productivity. We should recognize that productivity is just that, the results of increased innovation. Just as it is not possible "by taking thought to add one cubit to his stature,"(Matt. 6-27) it is not possible to add productivity to our society by talking about it. Productivity is a result of innovation, not vice versa.

Development of Innovation and Technology Transfer via Entrepreneurship

Policies to Develop the "Art of Engineering"

The role of technology in America and many of the developed nations is changing. Much of the creative effort normally associated with engineering is presently being absorbed in complying with the regulations imposed on industry through administrative law. An equivalent component of creativity is also employed in the development of the regulatory details, the measurement and implementation procedures as well as in the area of enforcement, and the inevitable compromises that deal with the trade-offs between what is desired and what can practicably be accomplished. With every weld on every automobile design being checked and identified for certification requirements, it is hard to delineate whether the design process takes place in Detroit or in Washington. That aspect of design which is associated with setting performance specifications and deciding on the allocation of resources and costs is more impacted and involved in the regulatory proceedings than most citizens realize. It is difficult to say who actually makes the cost decisions. The process of standard setting is highly complex. As has been pointed out so many times by Dr. Gerhardt Mensch of Berlin, the standard setting process also puts an upper limit on quality. The process is so consuming that once it has affected a compromise, it is very difficult for someone to improve the quality. Thus quality fixing is the same kind of evil as price fixing. However, since it is a more complex act, the "shoveling costs,"--the costs of making a decision are orders of magnitude greater. In America much of the decision seems to be outside of the engineering profession and involves the press, the public, the legislature, and other public interest groups. The process of environmental and quality setting thus requires a component of education of the public, involvement of engineers in the field of public policy plus the normal engineering requirement of being totally responsible for the application of the "best" science to the analysis and prediction of the consequences of use of a technological product by our society.

The engineer thus is completely involved in the interaction between government, industry, and the end user of technology. He has long been involved in the judicial process in the societal-industry interface and increasingly is involved in the policy formulation and political processes necessary to enlighten the society about the technological trade-offs that it is attempting to implement through the legislative and administrative law process.

Thus it is these larger demands for engineering talent that are most pressing at this time. The supply of practitioners for this arena is limited by the very few programs in engineering that deal with these complex issues. I believe that:

> The fact that the educational programs of the National Science Foundation have not addressed the correct problem and thus have not greatly aided in converting graduate education to appropriate areas of endeavor, is not reason for eliminating the program. That would certainly be indicated by performance thus far; however, the mismatch between the university's supply and the industrial demand has become worse, not better. The need is for complete re-orientation. If congress can only accomplish this by eliminating the funding for a period--then so be it.
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> A more appropriate solution, in my opinion would be for this Committee to redirect the NSF. Similarly, I believe that the need for social science research is always greater but the orientation has been wrong. Some of the blame for this problem, as I have hinted before, comes from the "cheap-shots" at social science that have perverted the grant making system. The social scientists themselves have also been largely to blame because they borrowed too much of their "arrogant style" from the sciences, and did not form, or articulate, hypotheses of what changes they would like to be able to predict or control before they started to gather the data. Admittedly, "social engineering" has a bad connotation in a free society, but greater degree of pragmatism and less deliberate obfuscation would have helped.

The traditions of engineering and particularly engineering education are thus need to be reexamined. Needless to say, the engineering profession has not paid much attention to its traditions because, as the "change agents" of society, it has been either responded to conditions or creating them. Our nation, through its government has brought us to the position where the major requirement for engineers is not for the highly trained specialist but for the intelligent generalist. Our engineering schools are providing this at the baccalaureate level but primarily teaches specialties with a low industrial demand at the advanced levels. This does not happen because it is not possible to prepare a meaningful curriculum at the graduate level, but because there are so few qualified practitioners at the universities to teach in these applied areas. The experimental programs in the National Science Foundation's Intergovernmental Science and Public Technology area have been addressing some of these needs but at this time it appears that their programs are quite misunderstood, even within the NSF.

The grand guru of business education, Peter Drucker, has pointed out that perhaps all of the professions include three categories: those who make things happen, those who understand what happens, and those who wonder what happens. The percentage in the first category is perhaps very much smaller than many of us would care to admit: yet in the field of engineering, the engineer who really matters is the one who decides what should be done, why it should be done, and sometimes how it should be done with an adequate amount of creative insight to involve that portion of the profession that understands how to carry out the details of analysis, optimization, implementation, manufacture, and all the other very complex and very demanding requirements needed to take an idea from the stage where it is a gleam in someone's eye to practical use for society. Clearly, the magnitude of effort required by our modern world is so large that the person or persons who make things happen must engage a large number of people who understand what happens, to help them and in turn together they must engage an even larger number of people who simply perform the task of implementing things that they are instructed to do in detail, in s step-by-step fashion. Increasingly, this latter category--those who perform only to detailed instructions will and shall be displaceable by the use of the kind of machines which obey instructions even better than humans who are called computers. However, because there will always be some new creative tasks, even very low level creative and decision tasks that have not been put into adequate instructional form for the computer, the least expensive machines to perform some tasks will continue to be human information processors.

The decisions of which tasks will be done by humans and which by machines will perhaps continue to be made by an economic, social, and political system that deals with the trade-offs between useful employment, efficiency and aversion to certain kinds of error. If humans tend to make one kind of error and machines make another kind, there would be a clear trade-off between which will be more problematical in various fields and thus cost analyses while complex, could be approximated. The decisions of where people replace machines or vice versa will continue to be a function of creative ways of deciding what the trade-offs are. In Drucker's categories, professional persons clearly have as their sole domain the creative dimensions and the social responsibility dimensions when they are the practitioners who make things happen. The legal systems do not know how to successfully sue a computer for malpractice, and thus our system focuses on finding the responsibility of the person who turned the switch and thus accepted the responsibility for what the computer may or didn't do. Unlike the scientist who can simply plead he was trying to discover knowledge, the engineer must accept responsibility as the applier of science. Hopefully, engineers will find mechanisms to collect the accolades for correctly applied science to personally compensate them for their failures.

The issue, therefore, in terms of developing the engineer of the 80's is the same as it has always been: it is to develop the engineer who is capable of accepting the responsibility that society gives him and that he accepts. That responsibility is to apply science to and for the good of society. That responsibility when abused is his fault. This does not mean, however, that we can expect a mere mortal to have sufficient foresight to understand future abuses of what is presently useful and presently benign technology. Those responsibilities must clearly be borne by society itself as it always has been. Perhaps this latter total responsibility is the effect we observe when, as it is often deprecatingly commented on by the pure scientists, it is observed that engineers are fickle and follow the money.

The massive applications of engineering talent in the U. S. are at present directed by the opportunities and/or responsibilities that have been federally legislated. This started with the defense efforts and was followed by space efforts and now by environmental and conservation directives.

The concept of the reasonable and prudent man is basic to the legal system, and it includes the idea that a professional can only be responsible to the degree that the best professionals understand and can anticipate. That responsibility thus requires that the professionals who accept responsibility must be the best prepared and most experienced of our technologists. There is increasingly little margin for being second best. If the bridge fails, the second best engineer will be held responsible for not being the best engineer, particularly if the society through its judicial system decides that it was reasonable to be better informed or more intelligent. Even more importantly, the persons who make things happen or who understand what happens must be willing to know when one is beyond his own range of understanding and requires the assistance of a better prepared expert, an analytic model, a set of experiments or an extraordinary precaution or training for the potential user of technology. Responsibility thus does not only include the decisions of what to do and how to do it, but the decision of when one does not have adequate information to proceed. Those questions of adequate information and the acceptance of the expertise of others are very complex, and yet they must be faced.

Much of the present environment in engineering education in America was developed by the engineering scientists of the World War II era. Their students continued in engineering education without the benefit of hand-on experience in engineering applications that they had when they were learning how to be applied technologists. In fact, many of the academically inclined who stayed at the universities after World War II had in fact themselves been educated as physicists. They had learned to do engineering, and particularly creative engineering design on the job. The philosophy that thus developed was that the university should teach science and defer the applications training to industry. Thus we are presently perhaps out of balance in our educational institutions with regard to producing the proper kind of educational experiences and role models for the present innovational need of the United States.

The need that is being unmet in both engineering and business education, is the need for the development of the engineers who can "make things happen." This kind of engineer must be trained within a studio environment. Preferably the environment will be benevolent in that it will allow the students to make benign mistakes and to learn from expert criticism. This environment will be very similar to the environment of the teaching hospital, it will more nearly resemble the kind of governmental or non-profit laboratory that has been closely connected with a university. The funding will be more nearly by block grants such as is common in Germany and the USSR. The particular American innovation in this reguard is, will, and should be the relationship between the research activity and the teaching activity. Governmental research labs may produce research results. When they do, they publish the results just as the universities do. However, the research results are more likely to be put into use by other societies that have emerging technologies, as contrasted to our own mature industries. Therefore increased expenditure in Federal research via non-industrial laboratory may actually decrease our technological advantage. Since many large corporations are even more bureaucratic than government, their research is also often not accepted by their own practitioners.

There has been a significant overemphasis of the myth called "technology transfer." It appears so often as some kind of process without including the intellectual and motivational issues of the persons involved in the process. We are all aware of the concept, NIH (Not Invented Here.) The concept here implies an arrogance, that comes from the sciences, that others ought somehow to appreciate their knowledge without realizing that the practitioners who apply knowledge also must have a well developed self-image in order to face the unknown dimensions within which they as engineers are attempting to be creative. In short, the best technology transfer happens when the developers of the technology are also involved in applying the technology. Since technology (know-how) is itself complex and interdependent with cost, marketing and production systems, language itself may be the delimiter of technology transfer. The highly stylized language of mathematics, drafting, block diagramming patent descriptions, hand waving and verbalizations of many kinds may leave out enough information so as to reduce the effectiveness of much interpersonal communication. Entrepreneurs are known to depend on the telephone and face-to-face meetings instead of publications and libraries.

Post World War II when American society realized that its technologists fell short of the requirement of being the Tom Edisons and Henry Fords, another societal invention was added. A new kind of institution, the business school, was developed as a band-aid for the ailing technologists. True, there had been some example business schools that predated this era, however, the massive demand did not occur until the 1950's.

In addition to the attempts, and I say the failure, of the engineering schools to deal with the whole problem of innovation, the business schools added the dimension of finance, accounting, and a restricted subset of marketing. I believe that the business school, band-aid is not yet sufficient to systematically produce the innovator-entrepreneur. All the evidence points toward the entrepreneurs as emanating from some sort of colonies of innovative people that have been called incubation centers. There are informal systems that grow once they have reached a critical size. It is not clear whether people interested in small, high technological industries come together to learn how or whether after they find themselves involved, some disruption occurs that sends them out to start their own enterprise. The phenomenon is not new. Detroit rapidly developed other automobile companies even though there was not nearby steel. Pittsburgh steel companies replicated even though the ore sources were most contiguous to the Great Lakes rather than the rivers. The mobile home industry developed in Indiana farm towns. The farm tractor industries in Illinois and Iowa, etc. These industries are characterized by where they started as new enterprises. Seldom did they relocate to coalesce around a market or even a source of supply. Rather the industries stayed where they started and where their founders lived.

The common dimension to innovation, in the sense of the total development of a new technological enterprise, is creativity of several dimensions -- product, finance, marketing and attractiveness to qualified and loyal colleagues. A common description for the persons that are central to innovation in the total sense is entrepreneur. This word from the French meaning one who "undertakes" -- risks his position, reputation, power and/or finances is not unique to a capitalistic society or to a mixed capitalistic plus socialistic society such as we find in the U. S. Let me digress briefly to point out that if U. S. enterprises were organized to return all the rewards of risk to the stockholders that would be capitalism. If it all went to the government, it could be called socialism. Since we couldn't decide, we split it down the middle via taxes and gave half the reward for risk to each.

Originally, in the U. S. the government was a silent partner, but because some of the business school types began to focus on short-term gain in an oversimplified quarterly financial analysis, our society responded and is now responding via regulations imposed through the democratic process to force what is deemed to be equivalent of a long-term or future concern on our corporate structures. I observe but cannot substantiate, that most of the ills which the political system is trying to correct are caused by large and mature industries, yet the remedies are presently being uniformly applied to both old and new enterprises. I also observe that when the founders of an enterprise remain in control, they tend to concern themselves more with the long-term effects and opportunities and perhaps are more sensitive to the total impact of their product or service. Legislated change that requires dramatic, capital and resource intensive response tends to favor large organizations. I suspect that sensitivity to political and technological changes that require quick response and creative interaction favor the smaller, more personal organizations.

The creative engineer (O Fr. engineer, from the Latin noun ingenium, "for native talent," hence something produced by this) is thus the intended innovator for which industrialized society has been seeking. He is, however, not easily found because he is rare in his pure form and, at least in the nations with mature industries, is often presently otherwise involved. To borrow again from Peter Drucker's concept, the engineers who can make things happen are a small part of the yield of our present institutionalized production of trained engineers. I believe that on the order of one percent of our engineering graduates at present fit the "make things happen" category. In the past, this has been adequate to keep the other 99% quite fully employed and thus supports the rest of the technologically-based U. S. economy. Now we either need to produce more of this 1% type, divert fewer to other pursuits (regulation, etc.) or accept the idea that other cultures will and are developing their own dynamics of product innovation based on their own evolution from an agrarian economy that fosters the first principles of self-reliance to a self-reliance with technological product growth dynamics. The limits of growth have not yet been reached and will not until technology reaches its limits of finding substitutes for necessary resources.

The governmental involvement in directing efforts of our scarcest resource, creative people, via policy and funding decisions have created our present apparent lack of relative industrial innovation as is especially apparent when one regards the international scene.[1] Many of the present innovation resources are directed elsewhere and many are not being fully utilized because our present state of uncertainty of our financial environment and our fiscal and regulatory policies. While crisis and uncertainty often breed invention, innovation requires reasonable financial and political stability.

I, thus, conclude that there is a necessity for change in engineering at the educational level. The educational system itself needs to be changed to prepare for the challenges of a civilian, world-market economy. Ingenuity (from the same base word as engineer) and the political and economic environment in which the disaggregated consumers continue to respect, support and are enthused by both basic and improvement innovations will be enhanced by any mechanism that enforces the entry of intelligent young practitioners into the field of engineering. However, any systematic procedure that could enhance the yield of the presently small percentage of the graduates who make things happen in any society will create a major increase of innovation, in direct percentage. I have earlier concluded that the portion of the personnel and labor base that "wonders what is happening" and thus prefers to follow simple instructions are replaceable by machines. This game has been called, "increasing productivity." The limits to an increase of manufacturing productivity relate to scale of the enterprise and the effects of costs of transportation and raw materials. The latter costs are often themselves predominated by the transportation component. Readjustments of productivity with market scale and transportation cost variables, will occur from time to time within Schumpeter types of exponential innovation and product growth comes as a basic component. As each product saturates its market to the point where there is only a replacement market, until the whole product is made obsolete by a new innovation, there will also follow a saturation of the productivity indicators.

The effect of the computer and automation is to free up the lowest skill levels of the labor force so that neither capital nor labor are the scare commodity. In mature industries, the capital depreciation has often occurred early on. The shortfall is in the availability of more innovators, given the fact that GNP is expected to increase. One might, of course, also ask should we expect innovation to continue to increase as well -- is there a limit to new ideas? This question has long been controversial; however, our present experience with the regulatory process suggests that if we were ever to really run out of new or creative ideas, it will always be possible to redefine the rules of the game and start the process of innovation all over again. The changes in availability and thus cost of natural resources appears to be adequate to drive innovation.

Thus far I have focused upon what the problem is, and upon what appears to me to be in need of change. Pointing out what is wrong has little value if it is not possible to add constructive suggestions. I shall limit my concluding remarks to defining the changes I believe are needed in education and to briefly describe our Innovation Center experience at Carnegie-Mellon University.

First, in the U. S. there will be little value in changing the engineering education without changing the education of business students at the same time. The business students must discover that forecasting is a technical question not a mathematical guessing game. It requires the best guesses of where to expect improvement innovation and when product obsolescence might occur. Reciprocally, the engineering students must discover more of the world of finance and methods of considering costs.

Both the engineering and the business students must discover that market analysis tools have little value in predicting the acceptance of basic innovations and have a respectable uncertainty in dealing with improvement innovation. Both groups must discover that their professional activities will deal with people as the final client for their creative acts and thus that they should learn to "role play" their clients' positions in order to understand them.

Both groups need to gain experience with recovering from major failures while they are in a benevolent environment. Both also need to develop their "artistic" and creative abilities in an environment of example, benevolence, and vicarious learning from each other's successes and failures.

The business schools and the engineering schools have both become so occupied with theory and analytic modeling that they neglect to even suggest access to the storehouses of knowledge found in handbooks, trade journals, patent files, regulatory and tax laws, and the information available via the telephone.

The development of communications and interpersonal skills should not be left as ad hoc as they now are, and also those who have difficulties should be sought out for development. The curriculum and so-called educational process has been so formalized that the faculty completely neglects the important issues like kindly telling a person that improvements in diction or help for stuttering might be professionally obtained.

The entrepreneurial and creative individuals need practice in deciding "what is the question" rather than "what is the answer." The most entrepreneurial will not tolerate being given information in which they are not interested and for which they did not ask. They intuitively know that the presentation, aside from being administered from the viewpoint of "take a spoonful, it's good for you," is trite and contrived to be efficiently presented. What is being oversimplified may be the clue to the next breakthrough. Because the normal lecture materials are delivered to each student in the same way, it is clear to those who strive for a unique experience that a lecture in a college classroom is perhaps analogous to showing a painting student a functioning printing press. The case study is like being sent to paint a canvas by the printed numbers.

What I am thus suggesting is that in order to increase the number true innovators from perhaps 1% to 2%, we need to consider a completely different system of education for at least a subgroup of the engineering and business profession. I'm not prepared to speculate what will happen if we were to develop an educational system for the creative elite and administer it to all the population except to suggest that by whatever measure the cost would be very high. I am, however, prepared to suggest that our present educational system is geared toward helping the student understand what is happening and hoping that they will learn to be creative. I suspect that we have optimized the process around presenting too much information per hour of faculty time so that in fact most of the students continue to "wonder what is happening." Creative students emerge from this system by pure accident.

I have suggested that in order to reorganize an educational system to develop more innovators, we investigate the model of the "art studio" or colony. We should examine the "teaching hospital" where the art of medicine is taught. We should look to the schools of drama where role playing is being learned and finally we should look to the "real world" where there may be many failures before there is a success. In this final situation, we should develop a procedure of allowing/requiring a student to participate in a sequence of harder and harder creative tasks. Perhaps this should first be done with an experienced practitioner present to orchestrate the recovery from non-fatal mistakes that finally make up that aspect of each of our own total education that is commonly called "experience."

What we have been doing at Carnegie-Mellon University, in the face of this basic philosophy, is to accept the fact that understanding and, eventually, learning to develop entrepreneurs will be difficult. We know that the body of knowledge and the theories will probably not be very good. Yet we believe this should not keep us from trying to find and understand some of the critical ingredients. In a sense our philosophy is that this topic of entrepreneurship -- of multidimensional creativity -- will be understood best in a clinical or a studio environment. At this stage, what we need is the technical and financial equivalent of the old barn and the experienced painter to see if we can start an art colony. The students learn by participating in more and more challenging activities with benevolent criticism.

The real innovation at the Carnegie-Mellon University, as far as I am concerned, is that we have developed an institutional framework for an incubator, or a studio in which entrepreneurs can work and obtain some of their original sustenance to get started. The following statement describes what our studio is all about.

THE CENTER FOR ENTREPRENEURIAL DEVELOPMENT, INC.

A NEW KIND OF
INSTITUTION, FOCUSED ON:

- Clinical Studies of the Entrepreneurial Process
- Technical and Management Assistance to Budding Entrepreneurs
- A University Affiliated Not-for-Profit Corporation to Limit Financial Liability and Protect the University's Assets
- A Not-For-Profit Revolving Fund to Finance the Initial Out-Of-Pocket Costs (Not for Salaries of the Principals)
- Common Facilities, Low Cost Rental Space, Purchased Access to the University's Services (Shop, Printing, Stores, Computers, Etc.)

We have set up the Innovation Center at CMU as a separate, nonprofit entity in very much the same manner as a clinic, art studio, or teaching hospital would be set up, and in the same manner in which not-for-profit urban development corporations have been established in various communities. As have the teaching hospital, the agricultural experiment station, and the community development corporation, we have obtained a 501-C-3 IRS status for the corporate structure. The purposes of our corporate charter are:

> To foster entrepreneurial activities and business and industrial projects as vehicles for research and experiment in the teaching and advancement of technology and management science; to assemble information and data, statistics and experience to be used as teaching materials for students of technology and management science and for research projects in those fields; in general, to conduct applied research in any area of enterprise for educational purposes and to improve the techniques and methodologies of management in all areas of private enterprise and public affairs.

We think this corporate structure has several important advantages: 1) It is financially separate from the university, so one can attempt greater risk than the normal university environment would allow. It allows the Center to do the things that corporate structure is basically designed to do; i.e., limit the liability to the specific project. 2) It allows the Center to have a more effective means of monitoring what is happening and of keeping the finances separate so the experimental nature of the entrepreneurial process and the business start-up process can be observed.

The separate legal entity and its separable political aspect is very important in that it provides a number of freedoms that would be even more important at a nonprivate university. We have a corporate separation and yet we have a synergistic relationship to the university. Originally, deans of the schools of business, urban and public affairs, and engineering were members of the board of the corporation. This means that relationships between individual professors who might be involved with the Center and the university can be monitored at some point, and release time for people who are going off to start businesses, payments for services received, and licensing of ideas outside of the university can be expedited. Associated with this framework, we have been involved in developing a number of courses and there is considerable opportunity for research projects and design projects, which can be done for university course credit.

The Center for Entrepreneurial Development has two parts: academic and clinical. The academic aspect of the center exists within the university context but, as soon as a project gets to the stage where it needs a corporate structure, then it is moved into CED Incorporated, a free-standing nonprofit corporation. CED Inc. was the subcontractor to the NSF project. The separate corporation allows us certain structural advantages. The engineering side of the program is primarily based in the Engineering Design Program, which offers a two-year interdisciplinary Master of Engineering degree.

A list of current projects with CED Inc., is shown in Figure 1. Our first project was begun in 1971 when the Center was organized.

CED Projects as of Dec. 1980

COMPANY	CED INVEST.	SALES	EMPLOY.	NEW CAPITAL
1. Compuguard (Sold 4/8/80 to Brown Boveri for $6,000,000--CED share-$90,000)	$40,000	$5,000,000	200	$10,000,000 tot.
2. Vectran	$20,000	$1,500,000	30	None
3. Transcomm	None	$8,000,000	50	$3,000,000 est.
4. Three Rivers Computer	None	$1,000,000 est.	20	$500,000
5. Sun Publi.	$1,000	$175,000	8	None
6. Peoples Cab	None	$350,000	50	None
7. Peoples Travel	None	$800,000	4	None
8. Iron Clad Agreement	None	$100,000	8	None
9. Jessika	$40,000	None--being reorganized		
10. Bactex	$60,000	$100,000	4	N/A
11. International Lamp Co.	$1,000	Out of business--no lossses		
12. Rehabilitation Equipment	None	$30.000	2	None
13. Para Comm	$25,000	None	2	None
14. Solfuel	None	None	1	
15. Taxi Accessories	$1,000	None	1pt.	
16, Road Locator	$500	None		

Figure 1. CED Projects

In each case where the chart shows a Center investment, made in the form of services or payment of out-of-pocket costs by the center, there is a small portion of stock assigned to the nonprofit revolving fund to help defray the potential losses due to unsuccessful ventures. The Center does not cover the cost of salaries to the principals. Those must be covered by the entrepreneurs.

By 1973, we had some experience in that Joe Sigel, a young man who was in our entrepreneurship course and who was interested in the advertising business, did a project in the course and ended up with three local advertising newspapers.

At that time, we also acquired the assets of a bankrupt taxicab company for one dollar. The taxi industry in the U. S. has twice as large in annual revenue as the mass transit industry; it is about a $4 billion a year business. With all the activities in the elderly and handicapped area, there is a potential for expansion of that business, particularly if some operating efficiencies can be developed. What we have been doing in the research area -- supported separately by the Department of Transportation -- is to look at the paratransit possibilities that are associated with increasing the efficiency of the taxi/paratransit industry. There are many ways to increase the efficiency because, basically, taxi fleets run empty half of the time and have an average of 1.2 persons in them the other half. Thus, if one can sell the back-haul space, or share the ride on the forward direction, efficiency factors of 2, or maybe even 4 might be obtained. Furthermore, there are a variety of opportunities for occasional taxis or commercialized ride sharing. The cab company is a completely separate operation in its research support, and it is now beginning to spin out some technology. We are organizing a company to market that technology. This part of our activity is an urban experiment station for service innovations.

> In 1973 our Center became a part of the Innovation Centers Experiment of the Intergovernmental Science and Public Technology division of the Engineering and Social Sciences Directorate of the National Sciences Foundation. The program on innovation had been specifically directed by OMB as a result of a Presidential Task Force in Industrial Innovation and was to be conducted in both the NSF and the Department of Commerce, with each having a specific aspect of the experiment in public policy development. At that time this Republican sponsored experiment did not have significant support within the National Science Board but the Associate Director of the NSF, personally fought the program through the system at a reduced level of experimentation. Grants of one million dollars each were made for five years to each of three institutions. Our Center at Carnegie-Mellon University was one of the recipients along with MIT and the University of Oregon.

Each of the University experiments addressed a somewhat different aspect of the problem. Note that the original intent of the experiments was for a larger scale of experiment with more dimensions of experimentation and the establishment of control groups so that the experiment, really a social science experiment, could be evaluated. MIT addressed the issue of increasing the amount of innovative experiences in the classroom. This was in course fitting as an educational experiment, but as would be expected some difficulty with the continuation of the activities after the period of initial funding. The University of Oregon, utilized its then close ties with The Oregon inventors Council to try to increase entrepreneurship by development of an invention evaluation system.

The grant from the National Science Foundation to Carnegie-Mellon University was to experiment with the development of a non-profit revolving fund that would fund the out-of-pocket, start-up costs of new businesses. A major effort was involved with the development of the institutional framework and the obtaining the appropriate tax approvals and establishing some operating principles. The major part of the effort previously described in the organizational description was accomplished under this experimental grant. Approximately one-half of the one million dollars was utilized in the establishment of the revolving fund. The fund was established by the provision of services in kind for the fledgling companies, with the requirement that when the companies were able they would repay the fund. The arrangement between the government and the Center, via the National Science Foundation, was that if the Center discontinued the experiment before the end of the five year duration of the grant, then the residual of the fund, up to the amount of the original grant would be repaid to the Foundation.

The Center established the principle that each major participant company involved in the fund, would also grant some stock to the fund so that those companies that were successful would offset those who failed. Another operating principle that has evolved over the years, is that the fund cannot be used for the salaries of the principals--but only for the out of pocket costs of the start-up operation. The Center has been housed in what was an abandoned building belonging to Carnegie-Mellon University and in several cases a major form of assistance was in the form of providing space and access to the shops and stockrooms of the University with the fund picking up the cost until the new firm could began sales. Initially the use of these benefits was limited to prototype development only.

> I am happy to say that the revolving fund is alive and well. The initial value has been hard to determine, but on the order of one-half million dollars was attributed to the establishment of the fund. The other one-half million went to University salaries and overhead. At this time three years after the termination of the NSF grant the fund is still active. Two of the companies have repaid their "loans," with interest and the stock of one of the companies was sold for some $90,000. The gestation period for the development of a new firm has been known to be very long and thus experiments of this kind require a long time for evaluation. We have been involved with some sixteen firms. Fewer than these had a financial commitment to the fund. Of the sixteen, one has gone out of business with no losses, one is reorganized after the founder had major surgery and moved to another state, and one firm is presently being liquidated by the Center as its only creditor.

In each project of the Center the intent has been to work with those entrepreneurs that lacked some degree of credibility or experience that could be provided by the Center. It is and has been the intention of the Center to stay involved with the Company, often by having a delegate on the board of directors, until such time as other investors, or venture capital could be brought into the Company. At such time the investors would take over the responsibilities of providing guidance and the Center would focus its attention on the next project. Thus far four of the companies have reached the stage of outside financing and a fifth has become self sufficient with only the Centers financing. The Center has been careful not to become involved financially when bank or other forms of financing have been available. This however still leaves a large amount of room for activity. After almost ten years of operation it has become very apparent that there are a large number of potential entrepreneurs that have all the required competence except the so called "experience" that so much of the financial community uses as a measure of potential success.

> On the other hand the limitations discovered by the Center include the fact that there may be a very small number of faculty members that are both interested and qualified

> to operate a successful Center at this time. The requirements that have been worked out at the Center affiliated with Carnegie-Mellon University have included protection against potential conflict of interest by the officers of the Center and preclude direct financial gain from any of the projects of the Center while and for a period after they have been associated with the Center. Thus the rewards to the Center officers must come from satisfaction and other means such as the Universities' recognition of the value of the association with the Center and the educational benefits therefrom. Since this project is so different from any activity of the university except maybe the Agricultural Extension Service or the Teaching Hospital at the Medical School, I suspect that only a few universities will attempt further investigation in this area, absent a major expansion of NSF or other support. On the other hand, if our technologists are again to become supreme in the private sector, world-wide marketplace, then we can not afford cost of not experimenting.

Let me continue now, to describe some more of the ventures and fledgling companies involved in our "Pittsburgh Experiment." Bactex Corporation, currently with about $55,000 of the Center's investment, is a project with the University of Pittsburgh in biological research. Patents are being developed by the Center. This came about when the University of Pittsburgh observed that even though Jonas Salk was on their faculty and Salk Vaccine had been developed there, the University had never enjoyed any of the resulting revenue. It was hoped that some mechanism could be developed to guarantee a return to the laboratory and the university. Three Rivers Computer Company was a spin out of Carnegie-Mellon University's computer center. Jessica Corporation is developing a noninvasive blood oximeter generated in the C-MU bioengineering laboratory. It is now going through its clinical testing. Compuguard Corporation is one of our early companies. It manufactures energy management systems for building complexes. Compuguard was one of the very few new companies in the U. S. to attract venture capital in 1973 and '74. Before being sold, some $3.5 million of capital was attracted from Cleveland and Boston because there have been no active venture capital firms in Pittsburgh in recent times. Compuguard has paid back the Center and has been sold to Brown Boveri (4/8/80) for $6,000,000 of which CED's share was $90,000. International Lamp Company is the only one of our business operations that has not survived. It was started by a student, also in the course, who heard about long-life light bulbs and thought he had a great future in selling. He discovered he was not very good at selling, and is now out of business; basically, he did not invest a great deal and neither did we. All funds were repaid. The student feels he learned from the experience. Transcom Data Systems was begun by another group of our early design students who started to sell PDP 11 time-sharing services. Recently the company was sold to a division of Compagnie Generale d'Electricite of Paris. They are now franchising computer software systems to a management consulting firm, and bookkeeping operations in Europe. They have been a DEC, OEM distributor for the PDP 11/45 computer with offices in Denver, Los Angeles, and Pittsburgh. Rehabilitation Equipment Company is run by a student who was very much involved in the Opticon distribution, building various kinds of rehabilitation gear. Basically, he was operating a $20-30 thousand a year business. He had open heart surgery and moved to Vermont where he is re-establishing himself, and another C-MU student is doing the Opticon repair.

Aside from these, there have been a couple of other related companies started in Pittsburgh.

One is a travel agency, that will eventually be coupled with the taxi company to provide complete transportation service with tickets sold in the cab via radio and computer, to any place in the country; essentially we are trying to tie ground transportation to airline transportation. Several of the taxi related developments are potentially being spun out in a corporation that is presently being organized. Some of the ideas presently in early stages of incubation appear below. Among these is the taxi meter which calculates the fare before the trip takes place permitting accurate calculation of shared trips. When route deviation occurs, no one in the vehicle is penalized. The central computer calculates the fare and displays it in the taxi. This prototype is operating in the Peoples Cab fleet in Pittsburgh.

C.E.D., Inc. Potential Projects

Being developed as of February 1981

- Para Comm Inc.--Shared Ride Taxi Meter System, which calculates the fare from computerized data base.
- Peranatronics Company--Fetal Heart Monitor (Product of Bio-Engineering Department).
- Peoples Cab Company Subsidiary--Retrofit compact autos for wheelchair accessibility, roof signs with built in direction locating antennas, computerized destination signs, design services.
- Paratransit Management Information Systems Company--Lock box accounting and business service.
- Carnegie-Mellon University Press--An instant book printing company-a vanity press without inventory.
- Road Finder Company--A general purpose vehicle locator system for urban areas.
-

Potential--Being Evaluated

- Combined Air-Ground Passenger Transportation Service
- Low-Cost Solar Powered Public Buildings for Occasional Use
- Low Cost Mass Spectrometer
- Residential Waste Disposal System

Thus far there has been an impact in Pittsburgh, providing role models for students at CMU and the beginnings of a clinical environment that is not suggesting potential questions to be investigated. Income from the successes is allowing us to start some more firms now that the one million dollar grant from the National Science Foundation to fund this experiment has been expended. More significantly, similar centers are being established in the United States and Canada. Thus far, new centers are established at the University of Utah, Ecole Polytechni que in Montreal, and at the University of Waterloo in Ontario.

A secondary effect is already beginning to take effect in Pittsburgh. New companies are being formed by people who participated in the first round of entrepreneurship. As of March 1981, we have been made aware of the following. Some worked with Center-related projects, others were affiliated only via the Design and Entrepreneurship course.

- Innovative Technology International, Inc., Monroeville, Pa. Krishnadi S. Pribadi, President (former partner in Compu-guard)
- Consolidated Services, Inc., Pittsburgh, Pa. David G. Obarski, President (formerly with Compu-guard)
- American Technical Institute, Pittsburgh, Pa. Jerry Kokalis, President (formerly Associate Director, CED)
- Munson's Exon Service Center Gil Conley, Partner (former mechanic, Peoples Cab Company
- Elcomp Systems, Inc. Ami Elis, President (GSIA student in the Design & Entrepreneurship course)
- New Kensington Cab Co. Robert Culbertson, Owner & President (GSIA & CIT student, Design & Entrepreneurship course)

Gentlemen we thus present the results of an experiment in the development of entrepreneurship. The Center has become self sufficient as far as the revolving fund is concerned. The overhead and operational costs of the Center cannot yet be born by the fund without depleting it. To do so would require a return on investment that would be phenomenal. At this stage the overhead of operating the Center is being born by a combination of the University, in terms of rent free space, and by my own efforts--often outside of my university duties. The concept has been proven in at least one case, companies were formed, they survived, and they were spun out of the Center with a net gain to the Center's revolving fund.

> I believe that Centers like ours can be replicated. The safest form would be the formation of a partnership relationship between ourselves and other universities attempting to form the same kind of institution. At this time there is a great deal of interest. I have been receiving so many letters or inquiry and so many telephone calls from universities, potential entrepreneurs, investors that I have not had the time, energy, or office resources to even respond with civility. Experiments such as the one at Carnegie-Mellon should be continued because the impact is greater than the direct result. The second generation companies demonstrate that the concept produces virulent offspring. This is the basic proof that the companies are more than the extension of the Center for Entrepreneurial Development', or Carnegie-Mellon's staff but rather are genuine entrepreneurial efforts. I fully expect that the regeneration concept will continue. The companies are now generating taxes at a rate that is many times the entire NSF investment, each year. Of course it is difficult to prove that the people involved would not be employed if the Center did not exist, but it is quite clear that many of them would not have found jobs in Pittsburgh. In just one year Compugard hired more C-MU graduates, eight, than any other employer except Ford Motor Co. and Dravo.

Mr. **Walgren**. Well, thank you very much for that refreshing perspective.

Mr. Brown.

Mr. **Brown**. Well, I want to extend my thanks to both of the panel members for very comprehensive and good statements, somewhat provocative also.

Dr. Baumann, you mentioned that more social science was needed and obviously you are aware of the degree to which some of our competitors have used American social science know-how to improve their operations.

Could you offer us an informed guess as to why we are having so much difficulty in legitimizing social science research in this country?

Dr. **Baumann**. I think I hinted at the answer in my statement. I think the reason is we find the social science field, an area in which the general public understands the words, but not the ideas,—as a fertile ground for pot-shots or cheap shots. So we forced the Foundation, in particular, to fund the esoteric areas that would not get a "golden fleece award" because it wouldn't be understood by the public and the press.

Mr. **Brown**. That sounds reasonable. We were at a hearing yesterday with another agency, with NASA discussing some of the problems of transfer of space technology to commercial development and the conversation came to the point where the main problem was not the technology, but the physical, or not the physical technology, but the lack of institutional technology, the ability to innovate in terms of creating institutions that could accommodate themselves to complex situations.

It seems to me that more and more aspects of innovation, that is, ability to think creatively in new policy areas, new ways of organizing human beings may be an important component of the whole process of stimulating innovation.

Dr. **Baumann**. I agree completely. I think our problem is that our social scientists have tried to use what they thought was some model of "science" rather than what I consider a role model of "engineering." Thus they could not think about what the purpose of their experiment was and what their hypothesis was that they were testing and what value it would be if they knew how to control the parameters. On the other hand, people who read our social science read it because they want to apply it, and then they do.

Mr. **Brown**. I think both of us would agree that there are aspects of social science which are not as fully developed as the physical science.

Dr. **Baumann**. I agree.

Mr. **Brown**. It would seem to me that is an argument for trying to improve social science rather than for dropping it completely.

Dr. **Baumann**. I am on your side and yet I am also aware of the budgetary problems and whatever.

In regard to Mr. Walgren's question about the NSF Board's responsibility, I think that you should continue to treat this disease; because in my estimation the National Science Board is not a board, it is a club, and I am not referring to the technical definition of "board" and "club", but to the sociological one. I think the framers of the NSF law intended it to be a board.

Mr. BROWN. I don't have any more questions. Thank you, Mr. Chairman.

Mr. WALGREN. How did it get to be a club?

Dr. BAUMANN. Because it decided it had to have one of each kind on it. So it is a club, like Noah's Ark was.

Mr. WALGREN. Well, it doesn't take direction.

Dr. BAUMANN. In other words, it does not deal with choosing people, just disciplines. In my estimation the way people get to the Board, from my 20 years of observation, it is not related to their point of view, vis-a-vis science philosophy, or science policy. I think this relates to the question you were asking, "What should our science policy be?" I if you want to ask that of people, you need to get a different mixture of people to answer the question.

If you simply want to have one of each kind, then they will talk about the weather.

Mr. WALGREN. I wanted to ask, what happens to your, to both of your efforts, Dr. Baumann; I am thinking particularly of the set of innovations at Carnegie-Mellon without Federal help?

Dr. BAUMANN. Well, Art Buchwald, who I consider a good sociologist, had an article 2 years ago, where he pointed out if you have a successful program, no one in Washington will want to help you any more. You have to have one that fails and then they can all help you and give you more money.

We are sort of in between. The program is successful in that the revolving fund is intact and growing. But the overhead costs are not there and furthermore, everybody in the world seems to call and want more information on what to do and "Where would they apply for money?"

Mr. WALGREN. Mr. Havlick.

Mr. HAVLICK. I think two-thirds of existing innovation groups would go out of existence. In Florida, I think we would survive because we have been able to cut our dependency on NSF to 40 percent. We would lose an awful lot of our capacity to build our programs, as I indicated in my written testimony, especially in regard to developing the means as how to effectively relate to the private sector.

That may force us to make decisions we would not make if the continuation of the funding was there.

Mr. WALGREN. The Chair recognizes the minority staff, Mr. Scoville.

Mr. SCOVILLE. Mrs. Heckler had to leave, but she wanted to specifically recognize Mr. Cox in the audience.

Mr. COX. I am over here. Thank you.

Mr. SCOVILLE. One thing is obvious from the testimony presented here today. That is that innovation groups serve a valid function in terms of proving the potential of demonstrating the ability to improve productivity in one of the most important service sectors of the economy, namely, the public sector of Government activity. They do it by way of bridging the gap in the private and public sector and it becomes important because a large part of the economy is tied up in services. It is also obvious that innovation groups are not able to affect the entire State and local sector of Government on the basis of the budget that NSF is able to give you. This is true even if such groups eventually become self-sustaining.

I guess my question to both Mr. Havlick and Mr. Cox is: Beyond the fact that each of your groups is trying to become self-sustained, what studies or mechanism do you try to develop which will essentially enable your approach to be replicated and self-funded? Has it demonstrated its worth and how do you transfer and disseminate that methodology out into the State and local governments so they pick it up on their own as an absolutely worthwhile type of activity to be involved in? In other words, I see you as the "seed." How do you affect the wheat growing beyond NSF if it is even appropriate?

Mr. HAVLICK. In Florida, if I understand the question, we are committed to local governments' financial participation in the program. We were the first innovation group in the country to take that step and we did that with the full support of our policy board which is made up of elected and appointed officials.

Mr. SCOVILLE. Here is what I am getting at: This is the next step and I think you have obviously made a great step forward in developing this mechanism for becoming self-sufficient. What you really want to have is your movement as a whole become self-sufficient.

How do you get, if it is necesary to reach all State governments, little local governments in Florida, how do you get your example to generate on its own a second innovation group which can address something you participate in or not participate in and this becomes a much more self-generating movement than you see?

Mr. HAVLICK. Are you talking outside of the State of Florida?

Mr. SCOVILLE. Yes, inside and outside.

Mr. HAVLICK. OK, within the State of Florida right now through our communication system and program of meetings and on-site visits we are reaching 600 plus cities and counties and the State government. So right now we are not differentiating between a financially supporting government or nonfinancially supporting government.

I was really intrigued by what Dr. Baumann said about the sociology of innovation because you find that in local government, too. It just so happens for some reason, and I can't define it much beyond an individual's willingness to take risks and innovate, you will find some city halls very aggressive, very out front, very innovative and risk-oriented, and those are the governments you want in an innovation group. They will take the leadership. If they take the leadership and we succeed, then another wave follows who wouldn't take the initial leadership.

Then there are always those in the caboose, and sad to say, I think that is the majority. I think as we prove our concepts initially with that innovative group and get a second wave and hook the rest on, we can have a successful statewide program. At least in the Southeast, I think, if we were successful in Florida, we could definitely move the program without any support into perhaps the Carolinas using our momentum to build the same kind of support in those States.

We also have a national innovation network that meets regularly with all of the innovation groups in all States where we can exchange ideas and concepts.

For example, the southwestern innovation group picked up a lot of our philosophy on dues and cooperative workings and they are moving in that area right now. I don't think it is correct to expect every government in every single State would totally support it.

Mr. Cox. Mr. Havlick and I are in Washington today because we are coordinating our work in providing engineering management assistance to the small business community, in my case about four of the six States and in his, maybe largely one State.

At the same time, we covered the grounds with GM in Framingham, Mass., where we have a major assembly plant and Governor King of Massachusetts is concerned why Bob Cox can't capture some of the General Motors' interests in Framingham, Mass.

My written testimony discusses the example of Lawrence, Mass., where, with $10,000 of NSF funds and $50,000 of DOE funds and about a comparable amount of in-time support from the University of Massachusetts, the New England Solar Energy Center, the city of Lawrence and the Commonwealth of Massachusetts, we have identified and verified alternate energy sources in one city of 67,000 that will save $4½ million a year.

The NSF budget is 5.6 and that is going to be zeroed out. It took me $10,000 and 10 months to put that package together.

Mr. Havlick and I are going to blend Lawrence, Mass., with General Motors, and get that thing going.

On March 14, I am sponsoring with the Canadian Government four major companies' professional societies, the First International Thermography Building Diagnostic Program in Toronto. Seventy percent of the attendants there will be from the United States.

I have no money as of March 14 to send my own staff who developed most of the empirical data that is going into that which is being used by the American society of testing the material and the ASHRAE people to develop standards on building diagnostic procedures.

I can share with Mr. Havlick and, through our telecommunications system, other people such as municipal legislation, and we can even share it with this committee.

Mr. Scoville. I think you demonstrated the point I raised. I think the Federal Government has a valid role to play in this area, but only viewed as a "seed" because you cannot expect the National Science Foundation to undertake the support of what essentially, if it really is in the State and local governments' interests to do so, they should support. At the current time, after all, the Federal Government is in deficit and a lot of States are not.

Anyhow, I think you have given, from your example, a very good point on the value of the catalytic specialist for these programs. I hope that example is reflected in the eventual solution to the budget problem.

Mr. Chairman, thank you.

Mr. Walgren. Thank you very much and I appreciate what information you gentlemen have provided to the committee.

The hearing is adjourned.

[Whereupon, at 5:05 p.m. the hearing was adjourned.]

[Additional material submitted for the record follows:]

(short)

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3.4.81

Subcommittee on Science, Research
and Technology
House Science and Technology Committee
2321 Rayburn Office Building
Washington, D.C. 20515

Dear Subcommittee Members,

On behalf of our 5000 members, I thank you for the opportunity to contribute to your hearing on the NSF budget. It is unfortunate that time limits did not allow for oral testimony, however, the Federation will gladly respond to any questions that you or members of your staff may have.

Sincerely,

Philip Speser

Philip Speser
Special Assistant for
Science and Technology

National Council Members (Elected)
Bruce Ames
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Since 1946, the Federation of American Scientists has been active in encouraging the socially responsible use of science. Among our 5,000 members are over half the living Nobel laureates in the United States. The responsibility of scientists includes ensuring that the benefits of our research contributes in the most efficient manner to the economic well-being of our fellow citizens. Thus, we welcome this opportunity to express our views on the budget for Applied Science, Engineering and Innovation of the National Science Foundation. In this submission we shall limit our comments to programs targeted towards spurring industrial innovation.

Scientific research and development is essential for maintaining and improving our defense posture and revitalizing the economy. Unfortunately, those results of R&D which show commercial potential often are not transferred from the laboratory into commercial use. Even when there are technological transfers out of the labs, there is a regrettably long lead-time involved. At present, it takes approximately twenty years to move a scientific idea from concept to commercialization. This bottleneck, involving both research and development and their application, inhibits the performance of our economy.

R&D stimulates the development of new firms and growth in existing businesses. This process means increased employment opportunities. A comparative study of job growth in mature firms, innovative-established firms, and young-high-technology firms by the Commerce Technical Advisory Board, submitted to the Secretary of DOC in 1976, demonstrated that between 1964 and 1974, the mature firms increased employment at an annual rate of 0.6%, innovative firms increased employment at an annual rate of 4.3%, and young-high-technology firms increased employment at a rate of 40.7%.

R&D also contributes to the price and technological competitiveness of U.S. industries in the world market-place. In January of this year, the

Department of the Treasury's Office of Tax Analysis released a paper by George Carlson which discussed these contributions. According to Carlson, "Available studies indicate that a reduced R&D spending may have been associated with about 15% of the post-1960's productivity decline". As is well known, lower productivity means higher unit prices. Carlson also stated: "Although the U.S. merchandise trade balance has a large deficit ($30 billion in 1979), R&D intensive manufacturing goods have a substantial trade surplus." On the world market, technologically superior products can sell despite the fact their prices may be higher than prices for inferior goods.

Recent history has demonstrated that one of the most important contributions of R&D to our economy is its role as a catalyst for the development of new industries. In an epoch of world market, American firms have two options. They can rely on the same product and process technology as other international competitors and fight for market shares on the basis of price or become technological competitive.

When a firm relies solely on price competition, even if it prospers, the country as a whole loses. The U.S. firm is forced to locate its plants in cheap-labor Third World countries. We have traditionally seen this pattern in labor intensive industries such as textiles and footwear. As the January, 1981, "Report to the President from the Secretary of Transportation" argues, this pattern is now emerging in capital intensive industries like automaking. We are all familiar with the out-migration of electronic consumer goods production.

When an American firm becomes increasingly technologically competitive both the firm and the country prosper. Such competition requires offering products that no one else makes and producing them with technologically advanced, highly productive methods. The leading U.S. role in the computer and biogenetics industries indicates the wisdom of this approach.

No one wants to see the government invest in programs that the private sector can more effectively handle with the aid of market mechanisms. This is as true in the R&D area as anywhere else. R&D performance in the U.S. is concentrated in six industries: aircraft and missiles, electrical equipment and communications, machinery chemicals, motor vehicles, and professional and scientific instruments. A study by the Committee on Technology and International Economic and Trade Issues of the National Academy of Engineering found that in general, large firms in relatively oligopolistic markets tend to be the leaders in industrial R&D in our economy. For example, February 27th's Wall Street Journal noted in a lead article that IBM is seeking to exploit Josephson's Nobel prize winning theory of super-conductivity to develop a computer with a capacity far beyond anything planned for this decade.

In the private sector, the threshold question for an investment in R&D and its application is the same question asked with respect to any investment: What is the Return-On-Investment? As GM vice-president, Betsy Ancker-Johnson, said at last year's American Association for the Advancement of Science Colloquium on R&D policy,

> If the expected value of a high risk venture is less than, say, the return on a government bond, conservative --some would say "prudent"--management does not invest in risk. This situation has a direct effect on R&D. One must look either for very high payoff or very low risk programs, but the number of R&D projects which meet these elusive requirements is extremely limited.

and the NAE study summarized the bottom line when it noted that R&D and innovation will be performed by the private sector "to the extent, and only to the extent, that it is privately profitable."

The result of this threshold question is under investment in R&D and its applications. A task force report of the Industiral Research Institute (an association of 260 companies with technical research departments) recently argued:

> Since much of the benefit on any new technology does not accrue to the company that supports it but accrues to society as a whole, it is likely that many ROI calculations will undervalue the total benefits of innovation, and will discourage investment in R&D. Nordhaus suggests that these decisions may be correct for individual companies and yet less-than-ideal for the U.S. as a whole. A second factor, the extreme uncertainty in estimating risk and pay-off, raises real questions about the applicability of ROI calculations to R&D decisions.

Even if a project manages to clear the Return-On-Investment threshold, a number of questions connected with over-all firm strategy remain which often lead firms to decide against the investment. According to a 1980 study by Nat Robertson for NSF, U.S. firms ask the following questions in evaluating potential R&D projects and their application:

1. Will the R&D result in a new product or a new process that will significantly reduce the costs of serving a well-defined market?
2. Can the R&D results be exploited expeditiously by the firm's manufacturing and marketing arms?
3. Has the firm the financial capability to undertake the long-term risk involved in R&D and to make the capital investments necessary to commercialize the results, including their manufacture and marketing?
4. Will the R&D results be appropriate for proprietary protection either through patents of confidential in-house knowledge not easily duplicated?
5. Will R&D enable the firm to meet competitive threats from other businesses?
6. Does the R&D bring the firm into conflict with current or prospective government regulations?

During these economically troubled times, these questions mean that most firms are reluctant to invest in either R&D oriented towards technological breakthroughs or in commercialization of the results of such projects. This reluctance reinforces the inherent consequence of businesses' criteria for R&D. Harvard Business School Professor William Abernathy notes, over time, in most industries, "the predominate mode of innovation shifts from radical product innovation to incremental innovation and process innovation increases in importance relative to product innovation". Robertson states the principle behind this tendency: "Do not expect advocates of a present technology simultaneously to nurture a new, competing technology". Since many firms are currently burdened by the need to modernize their production facilities--despite under utilization of present capacity and poor cash flows--investment in increased technological competitiveness is taking a back seat to investment in less risky, quick return, increased price competition.

Many academics, from Peter Drucker to John Kenneth Galbraith, have argued that U.S. market mechanisms have encouraged our managers to be very apt at maximizing short term profits even if their actions reduce the long term performance of the economy. Abernathy and Hayes demonstrate in the July-August 1980 Harvard Business Review, short term profits require using existing assets as efficiently as possible. The current round of investments in capital equipment indicate that managers are beginning to expand their horizons to the medium term performance of their firms. Yet we still do not see attention given to the long term, which involves developing new products and processes that open new markets or restructure old ones. As Abernathy and Hayes put is, planning for the long term requires "imagination and a certain amount of technological daring" in addition to financial risk taking. In a January 4th magazine section article, New York Times business reporter Steven Lohr concluded on the basis of interviews with business leaders that imagination, daring, and a willingness to take risks are discouraged by the U.S. money markets.

Our concern over next year's inflation should not lead us to neglect the importance of inflation, employment, productivity, and technological competitiveness in the 1990s and beyond. Our brief look at private sector investment in R&D and its applications indicates that two types of targeted Federal investment programs are essential. Federal investment is most efficient when it is directed at areas where market mechanisms do not work: 1) stimulating the initial development of radically new processes and product technologies, and 2) maintaining the scientific infrastructure on which continued advances in existing high technology industries depend.

Appearing before a subcommittee of the Senate Budget Committee in January, Lewis Branscomb, vice-president and chief scientist of IBM highlighted both of these roles. Answering the question, what has been the historical U.S. government role in the computer industry, he replied:

> In the early years, the federal government's role was very important, for the computer industry was extensively stimulated immediately after World War II, which brought understanding of the computer's technological importance.

Answering the question where does the industry's technology currently come from, Branscomb noted that direct federal investment in industry was of minor significance. However, he emphasized the vital role of federal investment in universities and research institutes:

> The basic and applied research base of American universities is still the strongest in the world. This, of course, is primarily a federal and state government investment. Unhappily, university research support has shown virtually no growth since the 1960's although Presidents Ford and Carter made strenuous efforts to reverse that stagnation and begin to rebuild the intellectual base for our national progress.

Indeed, the development of IBM's super-computer relies on this base. When asked what was the most important thing Congress could do to aid the electronics industry to sustain and increase its productivity in the face of Japanese competition, Branscomb stressed the importance of planning ahead and urged developing the scientific manpower and knowledge base on which the industry relies. He added that this task was particularly important in an epoch of budget constraints.

The IBM position realizes that federal investments targeted towards stimulating industrial innovation are redundant for large, established industries. For these industries, sustaining and increasing federal investment in research projects, scientific education, and equipment at universities are far more important. It also confirms that federal investment targeted towards developing radically new technologies are vital for the initial development of such technologies.

The importance of programs such as the Division of Applied Sciences' "Coherent Areas" and Small Business Research, and the Division of Intergovernmental Sciences and Public Technology's Small Business Innovation and University-based Centers for the emergence of tomorrow's technologies is demonstrated by the contribution that small firms make towards the development of technological competitiveness in the economy. For every R&D dollar spent, small companies produce four times more innovations than medium-sized companies and 24 times more innovations than large companies. A study by William Scheirer in 1975 reported that between 1953 and 1973, about half of the major innovations produced in U.S. industry were made by firms with less than 1,000 employees and approximately one-quarter of the major innovations came from firms with less than 100 employees. The Office of Federal Procurement Policy published a study which states that small firms perform federal R&D at roughly half the cost of large firms. Nonetheless, through the government a far greater share of federal R&D investment goes to large corporations than to small businesses. This fact makes the NSF programs especially important for our future economic well-being.

The relationship between small firms and the development of radical product and process technologies should not surprise us. These firms are more likely new market entrants. Small firms are less likely to have the same stake in existing product and process technologies as larger firms with their under-utilized plant capacity. It is not surprising that a 1979 study by David Birch of M.I.T. concluded that between 1969 and 1976, firms with 20 or fewer employees generated 66% of all new jobs in the U.S. Jobs generated by advanced technology firms are not going to disappear in the face of price competition by technologically inferior goods made overseas.

NSF's small business programs are extremely sensitive to both the virtues and weaknesses of market mechanisms. Support under these programs is limited to technical feasibility studies and actual research. As we have seen (particularly where radically innovative R&D is involved), Return-On-Investment calculations are seldom favorable to such projects. Small firms have immense difficulty attracting venture capital. Once the research is completed, although it is still difficult for a small firm to attract capital, the firm at least has a product in hand which can be assessed by potential investors. The NSF programs properly leave this assessment to the marketplace by not providing further federal investment.

We do not wish to imply that there is no room for improvement in these programs. One area for concern is the tendency to fund projects involving small businesses from a wide variety of economic sectors rather than focusing on a more limited ranges where the potential for technological breakthroughs seems particularly high. The current approach makes it more difficult for small firms to build upon each others work in the process of establishing a radically new technology appropriate for highly efficient use by small firms. It means that the development of in-house capacity--both in equipment and staff--requires providing specialized R&D services on a contract basis to either large corporations or the federal government. A firm with a highly successful project is likely to attempt to circumvent the risks associated with seeking venture capital for further development and commercialization by licensing its R&D results to a large corporation or seeking to merge with one.

The reason for this configuration was suggested by Wayne Brown, director of the University of Utah's Innovation Center, at the last AAAS Colloquium on R&D policy:

> It should be recognized that small firms are not miniature large corporations. They do not have centralized corporate R&D labs, separate planning groups, or product development departments. In times of pressure from high interest rates or inflation, large corporations might reduce their internal R&D budgets, but they are seldom forced to eliminate that activity altogether. In small firms, however, incremental budget cuts in R&D probably mean complete elimination of some research projects, merely because of their smaller size.

The consequence of this configuration, which better targeting of federal funds can mitigate, is to require small firms to design their R&D projects which the exploitation of their results by large corporations in mind. The NAE study suggests that large corporations frequently choose complex, costly developmental strategies in order to block smaller, more innovative and aggressive, competitors. It also notes that in 1972, Blair found that some large corporations suppressed innovations to protect their markets. The economic necessity for small firms to design R&D with the strategies of large corporations in mind means even small business oriented federal investments often encouraged the development of a single generic technology for each industry.

In our approach to industrial technology we commonly assume that only those technologies which allow for large production-runs of a single product can be highly productive and economically efficient. The problem this assumption raises can be illustrated through an analogy. If we relied solely on one strain of wheat, our agricultural "gene pool" would be so limited that the first wheat disease would leave us starving. On the other hand, if we planted several strains of wheat, the larger "gene pool" would make it unlikely that any given disease would mean disaster.

Our dependence on large production-run technology makes us highly sensitive to market shifts and economic dislocations caused by the emergence of new technologies. Only the largest corporations can afford to exploit this technology and it is incredibly costly for them to retool before their equipment is fully depreciated--even if that equipment suddenly becomes obsolete. The consequences of our limited technological "gene pool" can be seen in the current malaise and "waste" of valuable assets in our steel and auto industries.

Our economic future demands better targeting of federal funds for small businesses to encourage development of radically new technologies appropriate for economically efficient utilization by small firms. Developing such technologies is a vital need which can be meet through careful federal investment. Aid for technologies based on large production-runs is no longer essential. Retargeting those funds towards basic and applied research in universities would ensure the scientific infrastructure that established high-technology, large production-run industries rely upon.

One thing is certain, the Reagan Administration's approach to the science budget process is going to promote neither radically new technologies nor a more adequate scientific infrastructure for industry. Supply side economics is meaningless in areas where market forces have been repeatedly proven irrelevant. We can only hope that the debate over the budget in this Subcommittee and elsewhere encourages the Administration to appoint a science adviser and to start thinking about the relationship between the programs in the science budget and its goals of enhancing our defense posture and revitalizing the economy.

Preliminary Statement

Prepared for the

Sub-Committee on Science, Research and Technology

by

Robert A. Cox

Director

New England Innovation Group

in support of

Testimony Presented

by the

Florida Innovation Group

March 5, 1981

Members of the Sub-Committee

Mr. Havlick, Director of the Florida Innovation Group, invited me to prepare this statement because our respective organizations are actively cooperating in applied research projects concerned with issues of (1) productivity improvement in both the public and private sectors, (2) economic development and (3) solving critical public problems through the more effective utilization of our science and technology resources in this country and throughout the world. Specifically, Mr. Havlick and I are in Washington to coordinate our work in providing energy management assistance to the small business community in our respective regions of the country. This work is partly the result of the Congress' concern with past efforts by the Department of Energy to meet this private sector need plus our own knowledge of the impact of small business on the continued economic viability of the local and state governments in Florida, and New England. All of our technology utilization activities trace their origins to the National Science Foundation's Intergovernmental Science and Public Technology Program. Almost alone, as this sub-committee is well aware, NSF has been the one federal agency responsive to the well-documented requests of local and state officials for better access to, and utilization of, the new technologies developed largely through federally supported research and development in our federal labs, universities and private sector.

The Florida Innovation Group is one of the newest applied research efforts supported by NSF. The New England Innovation Group (NEIG) is now the oldest of the multi-state technology utilization projects. Together, through the emerging National Innovation Network, we continue to develop better techniques for aggregating public problems and applying science and technology to this "market" of public needs. NEIG representatives have reported to this sub-committee on several occassions on the impact of our activities,and I know my Board of Trustees believe that Innovation Groups should be an essential part of this nation's "new beginning" strategy.

Thanks to the foresight of the National Science Foundation, the Congress, and in particular this sub-committee, has available to it several different models for transforming available technology into marketable products, processes and services. The Florida and New England Innovation Groups are just two operating examples that demonstrate - and we think rather successfully - how to create public-private, problem-solving partnerships. Specifically, we believe NSF's Intergovernmental Program has helped fulfill Simon Ramo's search for, "The professional who knows how to apply science and technology in a harmonious match with the political, social and economic conditions of the world."

If Innovation Groups are having the type of impact described by Mr. Havlick and the attached February 25, 1981,letter from the Berlin, New Hampshire,Public Schools to National Science Board member, Dr. Raymond L. Bisplinghoff, then why is this city ripe with rumors that the Reagan Administration intends to dismantle the NSF Intergovernmental Program? Has the New England Innovation Group wasted federal funds in transforming the research developed at the U.S. Army's Cold Regions Research and Engineering Laboratory into a new energy management industry? Were the NEIG Trustees in error in allocating NSF funds to help the Manufacturing Jewelers and Silversmiths of America, Inc.,find a solution to that industry's electroplating waste disposal problems? Am I, as NEIG Director, in error in cooperating with the Canadian Government, several American companies, and professional societies on both sides of the invisible international border in sponsoring the first International Infrared Thermography Training Conference in Toronto beginning March 14, 1981? Should NEIG have refused to help Lawrence, Massachusetts, the State Energy Office, and several private companies investigate how to save over $4.5 million a year through innovative new alternative fuel sources? Is the National Innovation Network contributing to our national economic problems by linking the NSF sponsored telecommunications research at the New Jersey Institute of Technology with the marketing capabilities of the Control Data Corporation? Should I inform Rhode Island Governor Garrahy that, based on the Office of Management and Budget's view of this nation's needs, NEIG will no longer be able to use NSF/ISPT funds to help his Department of Social and Rehabilitative Services develop and adapt new technologies for the physically and mentally handicapped?

Based on the information available to me as of February 18, 1981, I understand the answer to all of the above questions is yes. To me this means that the economic recovery of this nation will be initiated without a Presidential Science Advisor, without an Assistant Secretary of Commerce for Science, Technology and Innovation, and without an important partner in the technology utilization process - the National Science Foundation's Intergovernmental Science and Public Technology Program.

I urge this sub-committee to take Mr. Havlick's testimony and this supporting statement from New England and begin to rethink the logic of a "new beginning" strategy which apparently overlooks both the value of applied research and the dynamics of the public-private cooperative partnership approach to fulfilling the economic and social needs of the American people.

The New England Innovation Group will submit more detailed information in support of this preliminary statement by March 16, 1981.

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(2/81)

Increasing the Productivity and Strengthening the Problem-Solving Capability of State and Local Government:

THE ROLE OF THE NEW ENGLAND INNOVATION GROUP

A Statement Prepared for the
U.S. House of Representatives
Science and Technology Committee's
Science, Research and Technology Subcommittee
by
Robert A. Cox, Director
New England Innovation Group

These remarks are submitted to the Subcommittee in support of preliminary testimony given at a hearing on March 5, 1981. The NEIG staff, Board of Trustees and the state and local officials participating in NEIG programs appreciate the opportunity to submit this record of NEIG's role in improving the productivity and strengthening the problem-solving capability of the public sector in New England.

"Now as we enter our third century, science, engineering, and technology are more important than ever in meeting the challenges and opportunities which lie ahead for this Nation and the world. The bill that I am signing today -- the National Science and Technology Policy, Organization, and Priorities Act of 1976, H.R. 10230 -- will help us in meeting those challenges. It outlines a comprehensive policy for achievement of our national objectives through the effective utilization of science and technology."

(President Gerald Ford, May 11, 1976)

"With chronically slim resources, the National Science Foundation has supported a versatile array of experimental projects aimed at linking state and local governments with scientific research and technology... In the face of skepticism, NSF has hung tough in its belief that modest but strategic investment in intergovernmental science will yield benefits in terms of productivity and service delivery. It is a refreshing glimpse of the better side of government."

(William D. Carey, American Society
for the Advancement of Science)

"In the opinion of this writer, institutional R&D offers at least as great a potential for benefits to modern civilization as does technical R&D...the federal government should play a role in sponsoring such institutional research."

(Richard Speier, Heritage Foundation,
Agenda for Progress 1980)

Over the past fifteen years the National Science Foundation has invested less than $40 million in intergovernmental science activities. The purpose of this testimony is to provide the Subcommittee with a glimpse at the operation of the New England Innovation Group, a five year old applied research experiment funded, in part, by the Foundation's Intergovernmental Science Program. I hope the Subcommittee, upon review of this material, will share the conviction of many familiar with NEIG that the region needs the Innovation Group now more than ever. The new Administration's commitment to increasing the responsibilities of state and local governments will put new pressures on already burdened policy makers and operational personnel at these levels. NEIG has demonstrated, through a diverse set of initiatives (several of which are described below) an ability to link state and local governments with scientific research and technology in productive ways.

This intergovernmental technology utilization experience could be of inestimable value during the transition to greater responsibility for the delivery of public sector services by state and local governments.

Background on NEIG

The New England Innovation Group (NEIG) is a non-profit corporation which operates a six-state intergovernmental science and public technology program. This organization was formed in 1975 through a cooperative effort by the Rhode Island League of Cities and Towns, the Naval Underwater Systems Center, the U.S. Department of Commerce and the National Science Foundation. The basic problem NEIG's activities address is the fragmentation of both technical resources and users and the lack of communication between these two groups.

In recognition of the profound impact this problem has on the economic, social and political life of New England's local and state governments, NEIG has sought to establish a functioning intergovernmental science and technology network linking, through communications and practical assistance projects, those with needs (users) with public, private and academic resources. In this manner the Region's public sector problems are more effectively aggregated, new sets of resources are made more readily accessible and the resulting new partnerships and increased capabilities stimulate the process through which research and development is transformed into marketable end-products or services.

NEIG's approach is characterized by (a) policy direction from a Board of Trustees composed of local, state and federal officials along with academic and private sector representatives; (b) emphasis on technology utilization versus technology transfer/technical assistance; (c) networking users and suppliers; (d) encouraging existing agencies and best performers to take the lead in projects; and (e) providing on-going technical and administrative support to local and state officials.

In a Congressional Subcommittee report released in 1979, the New England Innovation Group was described as "a success because it combines substantial intergovernmental experiences with an enthusiastic commitment to experiment with new institutional approaches".

In the first three program years of the New England Innovation Group, the applied research objective was to "define and establish a functioning technology utilization management system sensative to the needs of local and state officials and the political and economic realities of New England". This has been a dynamic process which is described in NEIG's Fourth Anniversary Report.

NEIG's 1975 Planning Phase proposal identified, and the Policy Committee (after June 1979, the Board of Trustees) approved in October 1976, the following policy objectives for NEIG:

1. Assist local and state governments to systematically assess their operations, define their needs, and establish priorities.
2. Stimulate the interest of federal, educational and industrial science and technology resources in the needs of local and state governments.

3. Coordinate and disseminate user needs to appropriate public and private technological resources.

4. Assist the users in adapting or modifying scientific and technological knowledge to meet their needs.

5. Aggregate user requirements for achieving economy of scale and cost-benefit savings.

6. Encourage the commercialization of scientific and technical knowledge in a manner which will enhance both the economy of the region and the quality of life for its citizens.

7. Develop financing arrangements where capital is the barrier to innovation.

8. Expand local, state and federal cooperation in policy development and implementation.

The Planning Phase also provided an opportunity for NEIG staff to identify and document the most pressing constraints to the utilization of scientific and technological resources by state and local governments. These include:

1. Diverse local government needs require intergovernmental approach.

2. Staff and financial shortages in local governments serve as barriers to innovative investments in science and technology.

3. The short term focus of public officials makes longer term results less attractive.

4. Inadequate follow-up capabilities of existing organizations.

5. There is inadequate understanding by some federal and academic resources as to their potential role in public technology activities.

6. A lack of incentives for existing resources and users to cooperate and/or share political power.

7. There is a reluctance by the private sector to invest in developing public markets for commercializing science and technology.

8. Information dissemination without follow through can create frustration among state and local officials.

9. The absence of a broad-based active federal program on public sector science and technology utilization.

Despite the significance of these constraints, the Innovation Group has been able to achieve an impressive level of success in its efforts to facilitate the utilization of science and technology in New England.

Highlights of the NEIG Technology Utilization Experience

A number of the technology utilization projects with which NEIG has been involved since 1975 are briefly described in the attached memo from former NEIG Board President Vincent A. Cianci, Mayor of Providence, to William Wetmore of the Intergovernmental Science Program at NSF. They represent an accurate sample of the diversity of NEIG's activity as both a bridge and a catalyst between the public and private sectors. These projects have served to:

A. Increase the capability of public sector personnel to respond to resource management issues posed by problems with scientific or technical dimensions.

B. Sensitize the private sector to the market potential of an aggregated state and local user community.

I would like to draw particular attention to the lessons learned through NEIG's projects with the Rhode Island and Massachusetts jewelry industries (see Attachment A), the Lawrence Economic Development/Energy Project (see Attachment B), NEIG's Building Diagnostic and Energy Management Program (see Attachment C), and the Information Retrieval/Communications Project (see Attachment D).

Each of these projects illustrates the dynamic methods, requiring modification for each endeavor, which NEIG utilizes to broker technical resources with needy users. In the instance of the Jewelry Project, through the timely assistance of the National Science Foundation, NEIG was able to help the jewelry industry access technical resources from the university and private sectors while other federal agencies, such as EPA, demanded compliance with regulations without complementary on-site technical assistance. After a ten-month delay, the Economic Development Administration responded to this "strategic" investment of NSF funds by the Innovation Group by funding Phase I, Problem Identification, of this project. This was followed by EDA funding of Phase II, a $240,000 Project Implementation grant. All participants in this intergovernmental process agree that NEIG's brokering role was essential to the development of a timely response to a hazardous waste disposal problem affecting 30,000 employees working in 1,000 plants in nineteen communities in two states. Similar problems are being encountered in New York and Southern California where the jewelry industry has major activities.

In the Lawrence Project, NEIG served as the technical resource broker between the City, the State Energy Office, the U.S. Department of Energy and the private sector. In cooperation with all of the above, NEIG developed a detailed economic development/energy plan funded with a $50,000 grant from the Department of Energy, which provides the City with the tools for implementing a comprehensive energy management program in Lawrence. This document includes a profile of the City's energy use by sector, a list of energy initiatives the City can implement over a five year period, eight special projects, a community awareness plan, and a description of the project's networking process. The eight special projects emphasized the economic development potential of energy initiatives and included:

1. Municipal Energy Office Plan
2. Alternate Fuels Demonstration Plan
3. District Heating Assessment Plan

4. Financing Energy Improvements: A Revolving Loan Fund
5. Economic Development/Energy Impacts
6. Non-profit Energy Corporation Plan
7. Passive Solar Demonstration Plan
8. Community Solar Education/Outreach

The City of Lawrence is presently exploring the implementation of several major projects in this plan, such as use of coal-oil mixture and peat as alternate fuels for private and public boilers in the City. Throughout this project, NEIG worked with the private sector, all three levels of government and university resources to present an innovative set of solutions to one of the most complex issues facing industrialized Northeast-Midwest communities. A great deal of interest in this project has already been expressed by individuals and organizations throughout the region and a follow-on dissemination/replication proposal is presently under consideration by the U.S. Department of Energy. None of this would have been possible if NEIG had not been able to use NSF funds during the critical "developmental" phase which began in February 1979 and extended through April 1980. Incidentally, Congressman James Shannon convened a meeting of utilities and other private interests in December 1979 which resulted in expressions of full support but no offers of private financial participation.

Since 1976 the Innovation Group has sought to demonstrate to both the private sector and public officials the usefulness of infrared thermography in diagnosing building energy consumption. This effort has encompassed extensive demonstration projects in state, municipal and residential buildings and regular cooperative activities with the infrared thermography industry.

The training and certification of qualified infrared technicians has been a major concern of the Innovation Group, which recognized the importance of quality control to such a young industry in the field of building diagnostics. This concern has culminated in the International Building Thermographic Training Program taking place in Toronto, Canada, this month. NEIG's contribution to this field has also been manifest by the creation of committees on the role of infrared thermography in building energy management within the American Society for Testing and Materials (ASTM) and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).

The NEIG Information/Communications Program (described on page 17 of our attached Anniversary Report) has conducted over 500 searches for state and local officials in New England and has linked up to 50 organizations in a computerized communications network. NEIG is recognized as a leader nationally in the use of computer technology to search large technical data bases in a timely manner. In light of this extensive experience the Control Data Corporation contacted NEIG in 1979 to explore a cooperative agreement which resulted in NEIG's testing CDC's Local Government Information Network during 1980.

NEIG staff also has been instrumental in ensuring the inclusion of community access provisions in Rhode Island cable TV franchise licensing regulations.

The aforementioned diverse experience with technology utilization at the state and local level has added considerably to the state of our knowledge about the innovation process. Notwithstanding the insights gained about the technical and institutional barriers which must be overcome to succeed in this environment, NEIG has identified the following unresolved strategy questions and concerns.

Research Questions

The New England Innovation Group has been evaluated, formally and informally, throughout its existence by its Board, staff, and observers within and outside the Region. NEIG has been found to be a highly successful intergovernmental mechanism in a field of endeavor which is complex and largely uncharted.

NEIG's efforts at public sector innovation have been so effective that, in addition to requests for assistance from our user community, other entities with the same constituency (e.g., city, state and federal agencies) are increasingly turning to NEIG to play the role of broker between resources and needs. While NEIG has been able to accomplish a great deal in a relatively short time, a number of policy and programmatic issues remain. Many of these issues are inherent to the process of intergovernmental innovation and have been the subject of a number of theoretical analyses by researchers observing various experiments throughout the country.

1. Identifying the point when the adoption of an "innovation" becomes self-generating; i.e., the use of infrared thermography as an energy management tool.
2. Determine how much to invest in the "diffusion" of science and technology in order to achieve a rate of adoption which will become self-generating; i.e., utilization of wetted salt.
3. Determining the appropriate allocations of resources, essential to successful technology utilization; i.e., information dissemination vs. adaptive engineering.
4. Projected reductions in NSF's Intergovernmental Science Program budget can seriously restrict NEIG's response capability to the needs of local and state governments. Without minimum support from NSF, the National Innovation Network can be "captured" by federal mission agencies rather than serving as independent intergovernmental catalysts and technology brokers for local and state officials.

5. The federal government continues to find it difficult to coordinate a response to an agenda of local and state problems.

6. Despite several dramatic examples of successfully utilizing federal laboratories in NEIG projects, laboratory participation in NEIG activities remains an unreliable and high risk undertaking.

7. The federal government, especially the Executive Branch, has essentially overlooked the commercialization potential of science and technology in the local and state government sector when developing recommendations for increased national productivity. The six states, 1600 local governments and 1300 school districts in New England represent a $16 billion per year regional industry.

8. Adhering to a strict policy of pre-selecting a single generic class of actors as lead participants in all projects (i.e., municipal leagues) may not be the best way to network local officials so as to aggregate needs and facilitate commercialization.

Summary

The New England Innovation Group holds a unique position in the complex governmental environment of New England. NEIG has demonstrated an ability to identify and effectively respond to major policy issues such as energy conservation, resource management, economic development, and productivity improvement. Mobilizing the extensive -- though often inaccessible -- problem solving resources of the federal government, universities, and the private sector on behalf of state and local governments has been the essence of NEIG's success. Through a series of dynamic technology utilization efforts, NEIG has been able to create a new partnership involving politicians, scientists, technicians and public administrators. This network is now able, with the support of NSF's Intergovernmental Science Program, to continue its applied research activities designed to make the most effective use of available resources for solving problems which will shape the social and economic well being of our region and our country well into the twenty-first century. State and local officials want an active federal partner in their technology utilization program. We believe the technology utilization process must be an essential component of the Reagan Administration's "New Beginning". This Subcommittee's decision about retaining the National Science Foundation's Intergovernmental Science Program is the key to continuing the type of services NEIG has been able to provide over the last five years.

STATEMENT

SUBMITTED TO:

THE SCIENCE, RESEARCH AND TECHNOLOGY SUBCOMMITTEE OF THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

BY:

WILLIAM B. STAFFORD, DIRECTOR, OFFICE OF INTERGOVERNMENTAL RELATIONS, CITY OF SEATTLE

AND

CHAIRMAN, THE URBAN CONSORTIUM FOR TECHNOLOGY INITIATIVES

ON THE SUBJECT OF:

THE INTERGOVERNMENTAL SCIENCE PROGRAM OF THE NATIONAL SCIENCE FOUNDATION

March 16, 1981

I am the current Chairman of the Urban Consortium for Technology Initiatives. The Urban Consortium is a national technology transfer network of the 28 largest cities in the United States and 9 major, urban counties. Created in 1974 with seed money supplied by the National Science Foundation (Intergovernmental Science and Public Technology Program) and the Department of Transportation (Office of the Secretary), the Consortium is a cooperative applied research, technology transfer, and management information sharing program dedicated to improving the effectiveness and efficiency of local governments. Currently, it has an estimated annual work program of $6 million and support from 10 Federal agencies, among other sources of support. The Consortium is one of three national technology transfer networks, the others being the Urban Technology System (for mid-sized communities) and the Community Technology Initiatives Program (for small-sized communities).

The President's budget transmittal to Congress recommends that the National Science Foundation budget be reduced in FY 1981 by approximately 8%, a cut which we believe makes possible the continued development of the scientific and technical capability needed by our nation to cope with the challenges of the 80's. At the same time, however, it is our understanding that the President's recommendation is to eliminate local government technology transfer programs within the Intergovernmental Science Program unit because the programs are of "narrow focus" or "less immediate priority."

On the contrary, these programs are of critical importance to cities and counties throughout the nation, as well as to their businesses and their citizens. The program's purpose is to improve the management and operational effectiveness of local governments. The program does so by creating and sustaining networks of local governments which collectively develop and/or adapt, transfer and apply technology. Technology as used here includes sophisticated analytic methods, computer-assisted management information and resource allocation systems, and other kinds of decision analysis methods. In addition, the program conducts on behalf of its members state-of-the-art-and-practice investigations on emerging urban issues.

The program has simple, but important operating principles. It is guided by representatives elected from the jurisdictional members; the member governments decide which urban problems are sufficiently common and critical to become priorities of the work program; the low-cost preliminary background investigations on each priority problem help decide quickly whether the problem is without current solution or whether some of the member governments can share already developed and evaluated solutions; any further research deemed necessary is conducted or guided by local government practitioners; the solutions developed are widely shared among all interested local governments nationwide. In short, the decision to join collectively in the program was made by local governments; the program is conducted by local governments; and the decision to object strenuously to the proposed elimination of the program was made collectively by the participating local governments. This is not a program which was created in Washington's wisdom, which robs local governments of their autonomy and decision-making ability, which force feeds Federal solutions on local governments and therefore should be abolished because it serves no useful local purpose. It is a grass roots program important to participants; but also benefiting the country as a whole.

What has been the result of the program in the six years of its existence? The management practices of participating governments are continually being enhanced. Taxpayers benefit. Let me share just two examples.

1. Through its "Energy Dispatch" series, the Urban Consortium reported how the Baltimore Department of Education saved energy by increasing the efficiency of boilers in school buildings. Philadelphia adapted the idea for all city agencies and its own staff estimates the savings for Philadelphia will exceed $3 million.

2. Through the Urban Consortium's peer match program, San Francisco's street crime unit had the opportunity to train with New York City's similar unit. San Francisco subsequently produced a $1.3 million productivity improvement by doubling the ratio of arrests per officer.

I could continue with other examples, but let me summarize by saying that the Consortium has addressed definitively over 115 problem areas and currently has 50 technology transfer projects in progress. In each case, participating jurisdictions (and the hundreds of others who can obtain our technical guides and case studies without charge) can expect to achieve substantial savings, or avoid costs both by eliminating staff analysis otherwise necessary and by providing future services through least cost methods.

Why is this an issue of national interest? Without question, I believe the Federal government has a significant role in creating, encouraging, and sponsoring programs such as the Consortium. First, the Federal government is unique in having an interest in local governments spread nationwide. Many of the problems cities must deal with are national in significance but concentrated in local areas. Secondly, only the Federal government can fund significant R&D for local government at minimum cost. Individual city governments cannot by themselves generate the knowledge and technique needed to carry out their duties and in trying will generate unnecessary costs through duplication of effort. Third, the viability of America's urban centers is critical to economic revitalization. The chances for strengthening the nation are heavily dependent on supportive contexts for private investment in local areas. So the very time when revenues are being reduced and local governments are being given more operating discretion through the proposed shift to block grants, the Federal government should not abandon its interest in management capacity sharing and technology transfer. If the Federal government moves to rescind this program, it seriously jeopardizes its economic recovery program. On the other hand, if the Federal government were to make only equitable cuts in technology transfer programs, local governments could more certainly manage the rapid changes faced by local governments as the result of radical Federal policy shifts.

In closing, let me say I have focused on the Urban Consortium because it is what I know best and the program from which my city, Seattle, reaps countless benefits. But the case I have made argues as strongly for the continuation of two other similar national technology transfer networks. These networks, Urban Technology System and Community Technology Initiatives Program, serve the needs of mid-sized and smaller communities respectively. Its programs are outlined in Attachment A. In addition, the Intergovernmental Science and Public Technology Program funds regional associations of local governments known as Innovation Groups. In total the NSF in 1981 appropriated $2.3 million for local government technology transfer programs. It cannot escape your attention that in two examples cited earlier in this Statement that our nation has already received a return on that investment from the Urban Consortium program alone.

My colleagues recently gathered in Baltimore, Maryland for the 1981 meeting of the Urban Consortium and there adopted a Resolution which is attached to this Statement as Attachment B. In it, the 37 major cities and counties of the Consortium urge that the FY 1981 NSF appropriation for the national local government technology transfer networks and the intergovernmental science programs should not be reduced by an amount greater than any percentage reduction made in the total National Science Foundation budget. I trust you will reconsider the recommendation of the Administration for rescision of this modestly funded, but vastly critical program and authorize no less than $4.0 million for the local government component of this program in FY 1981 and again in FY 1982.

Thank you.

ATTACHMENT A

February 18, 1981

The Importance of National Technology Transfer Networks for Local Governments

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Annual grants of $700,000 for 3 technology transfer networks (through the Intergovernmental Science and Technology Program, National Science Foundation) support technology applications in 100 localities nationwide. Technology in the form of hardware, computer systems, and resource allocation methods assist governments to do more with less funds -- to improve management and operations while delivering cost-effective services. The program supports well the Federal purpose to promote productivity in the urban government sector. And because technologies developed, tested and adapted by these governments are available to all local governments nationwide, the limited Federal investment to stimulate innovation is leveraged many times over.

The networks are served through Public Technology, Inc. and their work programs are selected and directed by local elected and appointed officials. All three link local governments with the research resources of Federal labs, universities, and institutes to solve problems. These networks are:

- The Urban Consortium for Technology Initiatives (UC), comprised of the 28 largest cities and 9 urban counties. Formed in 1974, the UC for example conducts applied research and implementation training activities which: improve energy conservation, assist contract public services to private organizations, develop techniques to retain local businesses, better manage urban infrastructure, and enable urban governments to forecast revenues and expenditures on a multi-year basis.

- Urban Technology System (UTS), comprised of 30 mid-sized cities. The involved governments hire locally-funded technology agents who link with their peers to share problems and solutions. An independent evaluation done by the NSF shows that from 1974 to 1977, 12 jurisdictions in the network saved $21.5 million as a result of participation. Savings to date of all participants exceed $80 million. Sample technology demonstrations broadly shared include: cooperative computer-aided dispatching; and the use of microprocessors in traffic control. These and all other applications permit increased productivity with reduced staffs.

- The Community Technology Initiatives Program (CTIP), now comprised of 27 communities of 50,000 or less spread nationwide. Assisted by 7 circuit-riding technology agents on loan from Federal labs, the network applies technology to day-to-day management problems. Nearly 250 separate problems ranging from refuse collection methods to computer purchase evaluations have been solved for participating governments since 1977. Direct savings have exceeded $2.5 million to date.

To eliminate these networks would seriously inhibit local governments' ability to cope with fiscal stress, reduced staffs, and new urban issues demanding solution. Networks permit localities to solve once, not several times, problems shared by many. Cost savings and cost avoidance result. The prospect of reduced Federal funds to local governments especially demands that low cost proven programs which sponsor innovation and improved management be retained.

It is vitally important that the three national networks developed by cities and counties in concert with the National Science Foundation incur only their proportionate share of the overall NSF budget reductions.

ATTACHMENT B

URBAN CONSORTIUM FOR
TECHNOLOGY INITIATIVES

RESOLUTION

WHEREAS the Urban Consortium for Technology Initiatives was formed in 1974 by local government officials, elected and appointed, concerned with improving the capabilities of America's major urban centers to utilize research and development and with assuring that future research and development addressed the priority problems of urban centers in a practical way; and

WHEREAS the Urban Consortium has developed into a vital network of 37 jurisdictions serving as delivery systems for key local government programs of national interest to a total population in excess of 40 million, actively working to reduce the net effect of the tax burden on their constituents by strongly leveraging the modest Federal expenditures for local government research and development into cost-effective management improvements;

WHEREAS the Urban Consortium, seven years after its founding, has a proven track record of products and activities which have, for example: improved the multi-year revenue and expenditure forecasting methods of major jurisdictions; improved transit system productivity, demonstrated how to contract public services to the private sector, improved the ability to objectively measure service delivery performance, increased the ability to plan and manage for energy conservation, provide effective response to local business problems, and are currently working diligently in every area of urban service to help members manage with less;

WHEREAS the Consortium through its nine (9) standing Task Forces of senior local government officials, 50 urban research and technology transfer projects in progress, and several annual training workshops has expanded to become the single major forum for over 1,000 local government officials to confer regularly in a working setting to design, conduct and/or guide, and disseminate research on over 150 priority problems to their urban colleagues;

WHEREAS the Federal government has a unique capacity, which is in the national interest, to coordinate and support research and development to local governments because of their numbers, diversity, need to avoid duplicative efforts, and inability singly to fund significant R&D and also to assure the expert management of Federal funds;

WHEREAS the likelihood of reduced governmental spending, coupled with increased responsibilities and additional options for local governments, will put even greater strain on the capacity of cities and counties to effectively make management choices and satisfactorily meet the needs of their residents;

WHEREAS proposed, and possible, disproportionate reductions in intergovernmental research, technology transfer, and technical assistance in the modestly-funded local government programs of NSF, and other major Federal departments and agencies would seriously jeopardize the continued effectiveness of proven Federal/local partnerships for improving local service delivery;

NOW THEREFORE BE IT RESOLVED that the major local governments of America strongly urge the Congress and the Administration to maintain and strengthen the performance of urban research and development and technology transfer;

BE IT FURTHER RESOLVED that members of the Urban Consortium strongly urge that Congress and the Administration in their review of programs devoted to assisting localities to improve their management and technical abilities necessary for solving their own problems apply standards of national need and current urgency and not reduce spending for these programs disproportionate to Agency-wide reductions;

BE IT STILL FURTHER RESOLVED that the FY 1981 NSF funding for the national local government technology transfer networks (the Urban Consortium, Urban Technology System, Community Technology Initiatives Program) and the intergovernmental science programs should not be reduced by an amount greater than any percentage reduction made in the total NSF budget.

Adopted February 25, 1981
Annual Meeting, Urban Consortium
Representatives
Baltimore, Maryland

William B. Stafford
Vice Chairman

Albert H. Baugher
Chairman

Urban Consortium Member Jurisdictions

Effective January 31, 1981

Atlanta, Georgia: Mayor, Maynard Jackson; Chief Administrative Officer, Richard Stogner; Urban Consortium Representative, Richard Layton, Commissioner, Department of Budget Policy and Evaluation.

Baltimore, Maryland: Mayor, William Donald Schaefer, Urban Consortium Representative, Quentin R. Lawson, Human Resources Coordinator.

Boston, Massachusetts: Mayor, Kevin H. White; Urban Consortium Representative (acting), Micho Spring, Deputy Mayor.

Chicago, Illinois: Mayor, Jane Byrne; Urban Consortium Representative, Albert H. Baugher, Assistant Commissioner, Department of Planning, City and Community Development.

Cleveland, Ohio: Mayor, George Voinovich; Chief Administrative Officer, Willard Largent; Urban Consortium Representative, Vincent J. Lombardi, Director, Department of Community Development.

Columbus, Ohio: Mayor, Tom Moody; Urban Consortium Representative, Martin Jenkins, Deputy Finance Director.

Dade County, Florida: Mayor, Stephen P. Clark; County Manager, Merrett R. Stierheim; Urban Consortium Representative, William F. Hampton, Special Assistant to the County Manager.

Dallas, Texas: Mayor, Robert S. Folsom; City Manager, George R. Schrader; Urban Consortium Representative, Winston C. Evans, Director of Management Services.

Denver, Colorado: Mayor, William H. McNichols, Jr.; Urban Consortium Representative, Alan Canter, Director of Planning.

Detroit, Michigan: Mayor, Coleman A. Young; Urban Consortium Representative, Arletta Douglas, Executive Assistant to the Mayor.

Hennepin County, Minnesota: County Board Chairman, John E. Derus; County Administrator, Dale A. Ackmann; Urban Consortium Representative, Dale A. Ackmann.

Hillsborough County, Florida: County Board Chairman, Jan K. Platt; County Administrator, William C. Tatum; Urban Consortium Representative, William C. Tatum.

Houston, Texas: Mayor, James J. McConn; Urban Consortium Representative, Connie Williams, Senior Executive Assistant to the Mayor.

Indianapolis, Indiana: Mayor, William H. Hudnut III; Urban Consortium Representative, Eugene W. Waltz, Technical Assistant to the Mayor.

Jacksonville, Florida: Mayor, Jake M. Godbold; Chief Administrative Officer, Donald R. McClure; Urban Consortium Representative, Madelyn Levin, Administrative Assistant, Mayor's Office.

Jefferson County, Kentucky: County Judge, Mitch McConnel, Chief Administrative Officer, David L. Huber; Urban Consortium Representative, William Bardenwerper, Coordinator, Federal Grants.

Kansas City, Missouri: Mayor, Richard L. Berkley; City Manager, Robert A. Kipp; Urban Consortium Representative, David H. Olson, Assistant City Manager.

King County, Washington: County Executive, Ron Dunlop; County Administrative Officer, Shani Taha; Urban Consortium Representative, Shani Taha.

Los Angeles, California: Mayor, Tom Bradley; Chief Administrative Officer, Keith Comrie; Urban Consortium Representative, John R. Coombs, Assistant City Administrative Officer.

Maricopa County, Arizona: Chairman, Board of Supervisors, Tom Freestone; County Manager, Robert G. Mauney; Urban Consortium Representative, Robert G. Mauney.

Memphis, Tennessee: Mayor, Wyeth Chandler; Chief Administrative Officer, Henry R. Evans; Urban Consortium Representative, Nancy McGee, Manager, Bureau of Intergovernmental Management.

Montgomery County, Maryland: County Executive, Charles W. Gilchrist; Chief Administrative Officer, Robert W. Wilson; Urban Consortium Representative, Robert W. Wilson.

Milwaukee, Wisconsin: Mayor, Henry W. Maier; Urban Consortium Representative, Herbert A. Goetsch, Commissioner of Public Works.

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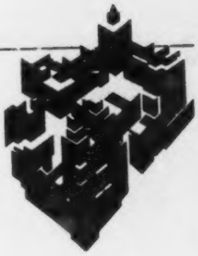

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March 13, 1981

Samuel I. Doctors, Professor
Business Administration
Energy Policy Institute
University of Pittsburgh
Pittsburgh, PA 15260

Dear Professor Doctors:

We are in the midst of considering the National Science Foundation Authorization for FY 1982. It was particularly helpful, therefore, to receive your letter of March 2 regarding the National Science Foundation's Intergovernmental Program. Your letter lays out the need for this program very clearly, and I would like to plan to include this in the record of the hearings if you have no objection. The letter will be a valuable addition to the testimony we have already taken regarding the Intergovernmental Program.

I am optimistic that we will be able to maintain funding for this program, although, there are many hurdles to be cleared, obviously. We will have to try to minimize the FY 1981 rescision in order to prevent the disruption of the program in addition to working to insure adequate funding for FY 1982.

Thank you very much for your interest and for taking the time and trouble to write to me.

Sincerely,

Doug Walgren

Doug Walgren
Chairman
Subcommittee on Science,
Research and Technology

DW:ktd

University of Pittsburgh
ENERGY POLICY INSTITUTE

March 2, 1981

The Honorable Douglas Walgren
U.S. House of Representatives
117 Cannon Building
Independence and New Jersey Avenue, S.W.
Room 117
Washington, D.C. 20515

Dear Congressman Walgren:

I am writing to ask for your help in saving the National Science Foundation's Intergovernmental Program. This valuable, effective, yet small program is threatened with extinction because of the Reagan Administration's proposed recisions for FY 1981 and its revised budget proposals for Fiscal Year 1982. The program's current budget for FY 1981 is $5,500,000 and tnat proposed by the Carter Administration for Fiscal Year 1982 was $5,600,000. I am informed that the Reagan Administration is, through the recision process, proposing to reduce the program's budget to $1,000,000 for FY 1981 (this figure representing carry forward monies deferred from FY 1980). Zero funding is to be proposed for FY 1982.

It is important that you know that I am not a disinterested party in requesting your support in saving the Intergovernmental Program. I have been a consultant to the program and have received support for background papers related to the program's development and its evaluation activities. In addition, I am the principal investigator on a substantial contract (estimated cost $444,000) awarded by the program to the CONSAD Research Corp. of Pittsburgh to evaluate the experimental phase of the Urban Technology System. This program was funded during the mid-1970's at a cost of about $4,500,000. The Urban Technology System placed "technology agents" in 27 local governments ranging in population size from 50,000 to 500,000 to try to determine among other things whether they could stimulate the use of innovations in solving problems of those governments. Conceptually, the System is in many ways analogous to the Agricultural Extension Service. If funding is not made available to complete the evaluation, the knowledge, results, and lessons learned from the System's operation will be lost, as will valuable knowledge for the research community useful in the evaluation of projects concerned with institutional change in the operation of local governments.

To help you understand my qualifications for supervising a major evaluation study, for serving as a consultant to the program, and for

PITTSBURGH, PA 15260

my following comments on the entire program, I am enclosing a copy of my resume, which includes a listing of my research publications.

The Intergovernmental Program's goal is to help state and local governments strengthen their own management capacity to use the resources of science and technology (research results, new technologies, new data and information, the expertise of scientists and engineers, and research and development facilities) in addressing issues and problems. The program's awards are mainly made to groups of local governments (referred to as "Innovation Groups"), state legislators, governors' policy and management offices, and national organizations representing state and local governments (e.g., U.S. Conference of Mayors, National Governor's Association, and National League of Cities). The program, working with state and local governments, has developed and tested a variety of strategies for achieving its goal. Many of these, in my opinion, have been very cost effective. In my own evaluation work on the UTS project, 53 selected case studies show an aggregate cost savings in excess of $20,000,000 for a combined Federal--local investment of less than 20% of that figure. The best evidence of this is that many of the program's major projects have been institutionalized by their grantees when these projects were completed and Federal support was terminated.

It is clear to me that there is a strong Federal interest in supporting the types of projects that the Intergovernmental Program has funded. I would be pleased to develop a detailed explanation of the reasons for this Federal interest, but for purposes of this letter, I will briefly summarize the major ones. First, the Congress in the past decade has passed a variety of legislation dealing with subjects of a scientific and technological nature (e.g., air and water quality, toxic waste, energy conservation, and occupational health and safety) mandating that the states carry out Congressional interest by developing implementing legislation and regulation. Second, the program's projects have helped state and local governments introduce new management and organizational tools and techniques that strengthen their capability to effectively and efficiently manage the estimated $90 billion of Federal intergovernmental transfers annually received by those governments. Third, the program's projects have strengthened the ability of state and local governments to examine, select, and use the results and other resources applicable to their problems that are awarded from the billions of dollars of research and development paid for by the Federal government over the past decade. Finally, at the philosophical level, I am surprised at the action being proposed by the Reagan Administration to eliminate the National Science Foundation's Intergovernmental Program. This administration has emphasized the importance of returning power, authority, and responsibility to state and local governments. If this is to be done effectively, these governments must have the capability to manage their resources, solve their problems, and carry out their mandated responsibilities under a wide variety of Federal legislation. The Intergovernmental Program, is, to my mind, a very important example of how a small Federal program can greatly strengthen the capability of state and local governments to achieve a major objective of the Reagan Administration.

Of course, I recognize that the National Science Foundation along with most other Federal agencies will most likely have to absorb cuts in their budgets for Fiscal Years 1981 and 1982, but I would hope that the Congress would exercise its historic role in ensuring that such budget cuts are equitably allocated across all programs of any given agency that is to be cut in its appropriations.

I very much appreciate your willingness to lend a sympathetic ear to this letter.

Most sincerely,

Samuel I. Doctors
Professor of Business Administration
Director, Energy Policy Institute

jae/SID

Enclosure

cc: Honorable William J. Coyne

THE COMPETITIVE CHALLENGE TO U.S. INDUSTRIAL TECHNOLOGY

R&D Responsibilities of Government Agencies, Universities and Industry

Lewis M. Branscomb

Vice President and Chief Scientist

International Business Machines Corporation

Armonk, New York

As the American public focuses its attention on the state of our economy, now challenged around the world by technically competent, progressive competitors, calls for government action and changes in government's role are increasingly heard. In the civil sector the attention focuses on new roles for the Department of Commerce and the National Science Foundation, as exemplified by the proposal for a National Technology Foundation. Defining the proper responsibilities of these agencies, establishing the needed resources and managing them properly will constitute a major challenge before the Administration and Congress in the next few years.

NATIONAL BUREAU OF STANDARDS
80TH ANNIVERSARY COLLOQUIUM

February 20, 1981

Not long ago, I read in the WASHINGTON STAR how a subcommittee of the House of Representatives had concluded that, in trade terms, America is "Japan's plantation," supplying wood and crops to Tokyo in return for high technology products.

Those of us in the scientific and industrial communities have been debating the importance of science to the economy for 30 years. But it wasn't until the Japanese showed us how to do very well the things we thought we were best at, that the whole country decided to take this issue seriously.

This concern has generated lots of presidential commissions and studies about innovation, productivity, basic research, engineering and technology, and a number of bills intended to promote all of them.

Some Americans want us to copy the Japanese, and turn the Department of Commerce into MITI. And some Japanese tell us what they think we want to hear.

For example, I recently asked a Japanese colleague what was the greatest strength of his computer development group. "Our people are very innovative," he said. "What do you mean by 'innovative'?" I asked.

"Each engineer is innovative every day," he replied. "He comes to work knowing precisely his goal for that day, and doesn't go home until it is achieved."

That's the kind of innovation we all respect. Hard work, personal savings, and concerted national action have brought the Japanese from the ashes of World War II to the most technologically ambitious economy in the world today. Meanwhile, this country has allowed itself to get inefficient, self indulgent, short-sighted, and unsure of its future.

There are almost as many views as to how the United States got itself into this fix, and proposed solutions, as there are economists who espouse them.

Every expert has a pet villain, and most of them are probably right. Lester Thurow, a distinguished MIT economist, calls it "death by a thousand cuts."

Perhaps the cruelest cut of all is that many people believe America has somehow lost its knack for innovation. Government attention has focused on innovation ever since the Charpie report, put forward by the Commerce Technical Advisory Board two decades ago. People tend to think of new products when you mention innovation. But our economic problems are at least as much or more related to sluggish productivity growth as to lagging product innovation. Where the Japanese show their strength is in process and manufacturing innovation, and very quick adoption -- often with superior engineering design for manufacturability -- of the product innovations of others.

Professor Thurow, whom I quoted earlier, has recently published a book called "The Zero-Sum Society." He notes that Americans save only 10% of their GNP, compared to 15% in West Germany and 20% in Japan. This shortfall in capital formation contributes importantly to obsolete factories and forms a barrier to the introduction of new technology.

Thurow estimates that to bring American savings up to even the German percentage would require a diversion of $114 billion in consumption to savings and capital investment. That calls for a formidable amount of self-restraint in a society that has become too self-indulgent.

What about our technology base? We Americans have become accustomed to a new experience -- we now expect leading-edge technology in Japanese and some other foreign products. We expect quality and sophistication where once we looked to foreign suppliers for the cheap and imitative.

Even in computers -- an area in which the U.S. still is world leader -- the Japanese have declared their determination to achieve a position of technological parity, if not leadership, whatever the resources and however long it may take. The skill and determination they bring to this effort does not exceed that of the U.S. companies with which they compete. But the commitment of the entire citizenry, and of the government as well, to the achievement of this goal is very impressive.

Let's take a more detailed look at the computer industry and the Japanese challenge.

in comparison with the historical performance of other industrial sectors. by every measure these are extraordinarily healthy and successful industries. Gleams in the scientist's eye as recently as 30 years ago, the U.S. data processing industries produce $70 billion dollars of revenue for our economy here and abroad, exhibit a long-term growth rate of 13 percent, employ 700,000 workers in their American operations and are generating new jobs at roughly the rate of 50,000 per year. They are industries whose profitability has financed much of their own growth and at the same time attracted a substantial amount of equity capital, financing hundreds of new business entries into the industry every year. They are therefore extraordinarily competitive industries, as measured both by new entries and by rapidly falling prices in conjunction with performance and functional improvements, and they exhibit a remarkable rate of introduction of new technologies and new products.

Any industry exhibiting this kind of technological and business dynamism is always in a state of change, and there are always challenges to be faced. As we move into the next generation of microelectronics technology, we will find the cost of entering the microelectronics business rising because of the great complexity and cost of production tooling. End-user product manufacturers will find the technical complexity of designing products in the most advanced technologies a substantial challenge. We therefore see many companies moving towards a vertically-integrated capability; that is, the ability to make both microelectronic components and to deliver end-user products incorporating them.

Another measure of the state of health of this industry is the extraordinary attention being paid by the governments of other nations to developing their own competitive capability. These competitive challenges testify to the success of an industry whose roots lie within American ingenuity and business leadership.

The Japanese certainly are our most rapidly advancing competitors. At the present time, their penetration of U.S. computer sales is modest, but they enjoy enormous success in consumer electronics broadly. They are just beginning to be a significant factor in the U.S. semiconductor industry. They do have a way to go, and there is no reason to panic. In Japan itself, only last year did a Japanese company exceed IBM's wholly-owned Japanese subsidiary in domestic gross revenue.

There is no reason for complacency, however, for the Japanese rate of technical progress is truly impressive. In terms of integrated circuit components, the fundamental devices on which computer and consumer electronic products are based, Japanese shipments increased from 19 percent of the worldwide volume in 1977 to 24 percent in 1979 while exhibiting an average absolute compound growth rate of 56 percent. In the same period, Japanese investment in integrated circuit research and development has increased from $120 million in 1977 to $258 million in 1979, an average compound growth rate of 46 percent.

At the present time, IBM is the only company shipping 64,000 bit-per-chip memory devices in large volume, but I believe all of us are impressed by the quality of Japanese 16,000-bit products, by their costs, and -- most importantly -- by the technology base they are building with which to challenge us both in components and in computers and other products in the mid-80's. There is little question that their rate of progress represents a serious challenge to the U.S.-based industry.

This extraordinary rate of progress in Japan has many sources, of which I believe the following four are most important:

(a) Japan focuses its priorities on sources of economic strength -- not weakness (as our government often seems to do). There is a national consensus in Japan that the information industry is to be one of the strategic industries on which the Japanese base their future. Every Japanese worker, government employee, and citizen understands that. They act accordingly.

(b) Both government and industry in Japan focus on competition in technological terms. The Japanese seem to be able to forego near-term profitability in the quest for long-term strategic industrial position. Japanese managements understand the key leverage of technology, and their investors and bankers back them up.

(c) The involvement of the Japanese government in the development of their key industries, in designing favorable tax and other financial arrangements for strategic industries, and in taking a very aggressive position supporting their companies' trade activities.

(d) By no means least important in this list is the quality and dedication of Japanese workers and management, the quality of their educational system and its production of engineers (twice ours), and the prestige which manufacturing technology and factory performance enjoy in the Japanese technical community.

These four areas of strength have little to do with research capability or scientific attainment. But it would be very wrong to imagine that U.S. scientific and engineering capability do not merit priority attention by government as well as the private sector as we seek to generate our national strategy for economic revitalization. To clarify the issues, let's look again at our computer and microelectronics industries and ask the chicken-and-egg question:

Is the health of the U.S. microelectronics industry driven by technological progress or by market opportunity?

The answer to this often-asked question is "both." Neither factor alone can keep the industry healthy. Scientific and technological progress has permitted the production cost of a given electronic function to fall annually by more than 26 percent, on the average, for 25 years. This falling cost, reflected in a highly competitive industry by prices falling at the same rate, both permits and requires volume growth in electronic shipments. This aggregate volume of shipments has grown faster than unit costs have fallen. That is, the demand elasticity for electronic and computer products has exceeded the technology's productivity gains and has led to very large growth in the physical volumes of manufactured goods and to net revenue growth in the industry. An industry with revenues growing at 13 percent which enjoys a technology price/performance improvement trend of 27 percent, is thus delivering 40 percent more computational power or other electronic capability to its customers every year, reduced perhaps to 30 percent by inflation.

Thus, the U.S. computer industry as a whole is exhibiting a real growth of more than 13 percent per year, minus the penalty of inflation. Unless this real growth continues, the demand will not be sufficient to generate the revenues that permit the reinvestment in technology that will continue the price/performance trend.

Thus, this very strong sector of the U.S. economy could fall on hard times if there should occur a failure of the upward spiral of growth, in which customer demand more than compensates for the ability of technology to reduce prices. This upward spiral could turn into a downward spiral, in which volume growth fails to produce revenue to cover falling prices. Then, companies would only be able to hold the profit margin needed to keep the technology going by cutting back on employment, and revenues would fail to generate capital to buy the tools to exploit the technology. Such a failure could occur for any of the following reasons:

(a) Failure of the technology to continue to advance sufficiently rapidly.

(b) Appearance of obstacles to demand-growth, such as government regulatory restrictions or a shortage of key science and engineering skills.

(c) Factors that unreasonably escalate costs (such as inflation, cost of capital, or tax increases).

(d) Failure to compete internationally, for whatever reason.

How can we avoid these four pitfalls?

The new administration is set on a course to address the regulatory and economic factors that can stifle demand growth, unreasonably escalate costs and restrict access to capital to finance growth. I assume the administration will also continue to pursue a fair and free trade policy based on the provisions of the G.A.T.T., which became effective in January 1981. These are indispensable steps toward a significant stimulus to private investment in growth industries. Companies can be expected to raise the needed funds to invest in product development and manufacturing technology, if inflation moderates, the cost of capital falls and investment is encouraged.

But what about the wellsprings of that technology, and the training of the technically skilled people to insure continued advances in the technology in the face of fierce international competition?

The right kinds of governmental investments in science and technology are not only welcome; they are urgently necessary.

But when the American government seeks to stimulate industrial science and technology by direct action, it often runs into difficulties.

The Bureau of Standards has seen such attempts made off and on for three quarters of a century. Old timers will remember the Civil Industrial Technology program, which proved a lightning rod for private sector objections to being helped by government technologists. The history of the AEC's encouragement to the commercial nuclear power industry is -- in retrospect -- no model for the government/private relationship. For out of the government's own conflicted role as both regulator and promoter of nuclear power came the legacy of lost public confidence that throttles the industry today.

The most recent and ambitious venture into public financing of private technology is the Synthetic Fuels Corporation. In this case it is clear that the government has undertaken to accept responsibility for making investment decisions for the oil industry, having captured the revenue for high risk investments through the "windfall profits" tax.

The Reagan administration is likely to back away from these forms of direct intervention. The administration will still have to decide what forms of indirect science and engineering support are justified.

One form of indirect support attempts to identify "generic" technologies for federal support, such as those authorized in the Stevenson-Wydler Act, enacted last year.

The idea of generic technology centers would not be bad if they focused on non-proprietary, publishable research, generally known to be useful by the broad community of industrial scientists and engineers. The difficulty arises when the word "technology" is invoked, since it is difficult to pursue technology in the absence of economic tests and market requirements.

If government-sponsored programs move closer to economic and market criteria for success, the political complications grow, for it becomes necessary to put the direction of such laboratories under the influence of industrial competitors. A host of difficulties may then ensue, ranging from competitively biased technical judgments to anti-trust problems.

On the other hand, if such laboratories attempt to work on commercial technology without the guidance of those aware of the economic and market requirements, a good deal of technical effort and money can be wasted.

I don't intend a blanket rejection of such proposals. Indeed, IBM participates in several university-operated and government-sponsored applied research programs in which a number of companies take part. I only observe that it is not easy for government to invest effectively in commercially important technology, without encountering political complications.

A classic example is the attempt of the Carter administration to bolster the competitiveness of the beleaguered U.S. automotive industry by federally sponsored research. Caught between Congressional exhortations to "reinvent the automobile" and skepticism about a government agency's ability to manage an automotive technology effort, the Carter administration adopted a plan for basic automotive research. The Department of Transportation would ask NSF to manage a program in fields of potential importance to automotive technology.

This project, acronymed C.A.R.P., was one of the first to be struck down by the in-coming administration. It was indeed a wholly unobjectionable project as far as research content was concerned. But it was very vulnerable to the objection that the public expectation for results would not be matched by the project's reality. A "basic research" program to "re-invent" the automobile is a contradiction in terms.*

Thus, I believe there is general recognition of the need for restraint in government initiated attempts to engage in commercial research, while there is growing conviction that a growing share of the federal research investment should be made, with ultimate use by the private sector in mind. Yet there is confusion in how these seemingly contradictory principles can be accommodated. This confusion has part of its origin in differing perceptions about basic, applied and engineering research.

* Lewis M. Branscomb, "Opportunities for Cooperation Between Government, Industry and the University," Annals of the New York Academy of Sciences, Vol. 334 (December 14, 1979), 221-227.

We have arrived at a point -- in the evolution of technology policy -- where the thrust is "back to basics" and common sense must be allowed to prevail. We will no longer deceive ourselves that a government agency can do a better job than private industry at evaluating the economic and market potential of alternative technologies. But I believe this administration must and will accord a high priority to strengthening the science and engineering research base on which private investments can build.

This brings me, then, to the question of research and education strategies for NSF and the Department of Commerce. The time is at hand to focus federal energies on the central government's unique responsibility for the nation's scientific and technical infrastructure. Key to this view of policy is:

(a) a more sophisticated view of the common distinctions between "pure" and "applied" research.

(b) a focus of federal concern on engineering capability as well as scientific excellence.

(c) development of stronger ties between university and industrial research.

(d) federal investments to ameliorate serious shortages in key technical skills, and

(e) attention to the knowledge and services with greatest potential to increase research and development effectiveness.

Let me speak to each of these points.

I have long believed that the NSF's distinction between basic and applied research has confused public policy in a most detrimental way. I have expanded on this view at length in a recent paper at The American Physical Society's New York Meeting.* I will summarize the point by noting that the NSF definition rests on the motives of the investigator. [Am I exploring the unknown driven by curiosity? (basic research) or am I looking for an answer to someone else's question? (applied research).] Useful as this may be to sociologists of science, it is not very helpful to investors in research -- including the federal government. What matters to the investor is, what is the likelihood that this research will lead to ideas or information of great significance or value?

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* To be published in PHYSICS TODAY, March 1981.

There are, in fact, two classes of applied research funded by government. One is what I like to call useful or applicable research -- known to be productive of ideas and answers that can be put to good use. This useful science is really not distinguishable from the conventional notion of "basic" research, except that a fraction -- actually a very small fraction -- of basic research deals with notions unlikely to find application very soon.

The second kind of applied research is what I call "problem-focussed" research, which purports to address and even provide solutions to identified societal problems. There is nothing wrong with investing federal money in such problem focussed research. It is the primary activity of the "mission-oriented" agencies. But in most cases it is not the right way to use either universities or national laboratories, for problem-focussed research should be carried out in institutions able to solve the problem when the research is done. Usually this will be the private sector unless the problem lies within the sphere of governmental responsibility.

In 1969, within a month of becoming Director of NBS, I sought a meeting with Dr. William McElroy, then Director of NSF, to solicit his interest and cooperation with NBS in what I called the "useful sciences." After a few months, I was given the opportunity to address the NSF senior staff. I confess my ideas fell then on infertile soil. But today there is a more sophisticated view of science and engineering and their dimensions of value to American society.

The NSB has encouraged and endorsed the policy of the NSF to integrate basic and applied science in all its research directorates. This provides the opportunity to pursue research of high value and significance in all the science and engineering disciplines. The NSF will continue to focus on investigator-initiated, competitively evaluated research but it will be in a much stronger position to respond to opportunities and urgent needs and to explain to its publics the value of its total investment in research.

This should put NSF in a stronger position to help university investigators to explore the excellent and useful areas of scientific and engineering work such as those pursued at the National Bureau of Standards. By the same token, I hope NBS will continue to make seminal contributions to science, taking full advantage of the power of the Bureau's measurement skills to open new doors to discovery.

The second issue requiring attention is the status of engineering capability in the U.S. There is no doubting the crisis in American engineering. The Japanese, with a smaller population, outproduce us in engineers two to one. Our engineering faculties are depleted. Two thousand tenure track faculty posts stand vacant. Instructional equipment is so outdated, many engineers must start their technical education anew after they are employed in industry. And, even in a recession, recruiting is especially fierce for electrical, computer and chemical engineers. Fifty to 60 percent of the engineering graduate students are foreigners, and the ratio continues to rise as the fall-off in the number of engineering Ph.D. candidates -- a fall of 30% in ten years -- is almost entirely restricted to the U.S. citizens.

The NSF's primary role is to support research in the engineering disciplines. To this end an Engineering Directorate is being created with the intention of strengthening research in these fields. Secondly, NSF has renamed its education directorate "Science and Engineering Education" reflecting new priority we intend to accord to ameliorating the crisis in engineering education.

The NSB does not believe that these responsibilities should be removed from the NSF and relegated to a new National Technology Foundation. They are our proper job, and we intend to seek the resources to do it. But the tasks proposed for the Technology Foundation are important and most of them do belong properly, in my view, to the Department of Commerce and to the NSF.

I believe the Commerce Department should share with others concern for the quality and availability of professional engineers and technicians, as well as the retraining of engineers in mid-career. The department should be knowledgable about the strong and weak components of the technology in different industrial sectors, and seek to focus national policy toward support for areas of strength and opportunity.

Most important, the Department should focus attention on the factory as an institution deserving respect and offering rewarding technical challenge. The prestige of manufacturing engineering needs to be restored by an infusion of the most advanced technical ideas and talent. Modern engineering design, production control, process technology, materials strategies -- all these are areas of technology which the D.O.C. should understand and whose health in various sectors can be assessed. I do not propose D.O.C. should finance the needed improvement in industry, but D.O.C. might well finance -- in collaboration with industry -- some of the needed upgrading of our engineering schools' capabilities, particularly those capabilities that could rapidly upgrade the productivity and technical agility of our manufacturing institutions.

Indeed, much can be accomplished without substantial federal expenditures by encouraging research collaboration between university and industry laboratories.

The National Science Foundation has a substantial program, which is being expanded, of grants to such collaborating partners. The funds may flow to either partner; the work is reviewed by technical peers and evaluated; and the results are expected to be published.

The real benefits from such a program go well beyond the specific research it finances, however. The most effective mechanism for ensuring that our technology properly stimulates our science, and that the science illuminates and sparks new technology, is to maintain the highest degree of cooperation and interchange within the professional, engineering and scientific communities that cut across university, industry, and government research enterprises.

An alternative approach to encouraging this interchange with universities also merits serious study, in my view. Congressman Charles Vanik of Ohio introduced a proposal last year (the Research Revitalization Act of 1980) to permit companies a 25 percent tax credit, in addition to the normal business deduction, for contributions to university-conducted research.

This, in effect, allows the government to underwrite the cost of university research that has been undertaken as the result of agreements entertained by the university and a company, without government's direct involvement in those discussions and agreements.

This approach has the virtue of minimizing the overhead expense and the bureaucracy attendant to receiving a direct grant of government money.

It puts the responsibility for deciding what university research is of greatest interest to industry in the hands of industrial scientists and engineers. It puts the responsibility for determining what industrial research needs are appropriately responded to by universities squarely in the hands of the university faculties. And it permits microdecisions on both issues to be made in the context of specific relationships.

I have already spoken to the issue of key technical skills. This is an area where the administration has yet to define a clear view of federal responsibilities. I am convinced that however diligently the states attempt to bolster science and engineering education, the effort will fall short without a federal leadership. Industrial philanthropy today meets 2.6 % of the operating costs of our research universities, public and private. Even a major expansion of industrial support will not relieve the federal government of its leading role.

Finally let me turn to the technical information and other services, offered on a national level, to promote the objectivity, efficiency and progress of both public and private research and development activities. Looking back over all the decades, there has been controversy from time to time about the extent to which the NBS should focus on help to specific industries or the amount of investigator defined basic research the NBS could afford. But there has never been any doubt about the value of the Bureau's work in measurement science, materials characterization, test methods and properties of natural matter and useful materials. To be sure, the Bureau has never claimed exclusive jurisdiction over these services. Nor has the Bureau failed to recognize that the information industry has an important role in providing access to this great body of useful information.

But now that the view of Government in a limited, helpful role has the endorsement of the electorate, the time is ripe for recognition of the extraordinary value to industry and to science of the basic NBS services. The Bureau's work in measurement science belongs in the priority core of the nation's science investments. This work is invaluable to industry, but is so widely shared it will not be performed or paid for by industry. And its value to the effective progress of science is just as unique as is its value to the efficiency of industrial research and development. Here too, categorization of work into "basic" and "applied" is mischievous and not helpful in making reesearch investment decisions.

How can these four ideas be applied to microelectronics technology?

Regarding "basic" and "applied" research, the problem is bypassed by the totally new and dynamic character of the fields engaged in it, from applied mathematics to solid state physics, ceramics, polymers and metallurgy, computer science, electrical engineering, production control, automated design, development and test.

University-industry collaboration has arisen quite spontaneously, and with very little federal stimulation or support. In California, North Carolina and Minnesota, the Governors have personally led the call for state investment in university-operated microelectronics science and engineering. Companies have invested hundreds of thousands of dollars in programs at schools such as Cal Tech, Stanford, Berkeley, Purdue, Minnesota, Duke/UNC/NC State and Cornell. But sooner or later, the federal government will have to come forward with substantial, continuing support.

Finally, the technical base for this technology touches about every area of NBS interest and competence. The NBS VLSI initiative can be very helpful by helping establish a firm foundation of meaningful and practical measurements on which all productivity gains must rest.

We all owe a debt of gratitude to Congressman George Brown for generating a national discussion of these issues through his National Technology Foundation proposal. And I've already indicated concern about the separation of science from engineering that is implied in the proposal. But there still remains the primary and highly desirable goal of Congressman Brown's proposal: putting together the package of efforts in both NSF and D.O.C. agencies to bolster the technological base for economic revitalization of this country.

This goal can still be achieved by the cooperative efforts of NSF and other scientific agencies, most especially NBS. Our roles are complimentary, but our purposes are similar -- insure that the scientific and technical capabilities of the U.S.A. are developed to the highest level.

I believe our leading engineers and scientists must make common cause. We must recognize that scientific leadership is indispensable to industrial leadership, as the Japanese are finding. We also must recognize that engineering skills guide reduction of scientific ideas to practice, and manufacturing engineering determines the productivity industrial workers achieve. If we are to compete successfully in growth industries, we Americans need to pull up our socks and take an optimistic view of what our brainpower can do to make our economy the world pace-setter it should be. Let's recall what Rudyard Kipling once wrote:

> "They copied all they could follow, but they couldn't copy my mind, and I left 'em sweating and stealing a year and a half behind."

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1982 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

TUESDAY, MARCH 10, 1981

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:10 a.m., in room 2325, Rayburn House Office Building, Hon. Doug Walgren [chairman of the subcommittee], presiding.

Mr. **Walgren**. The hearing will come to order.

Today, the subcommittee continues its authorization hearings of the National Science Foundation for fiscal year 1982. This is the second day devoted to one of the more important issues facing the Foundation—that of science and engineering education.

Last week we heard that we have a shortage of engineers, computer scientists, and the teachers to train them; and the shortages are appearing in other fields of science, as well.

We are also not doing a very good job of educating that majority of our people who will not become technical specialists. By comparison with Russia, Eastern Europe, and Japan, public school science education in America is not as good as it was, and is getting less so.

At our first hearing our witnesses outlined these problems in greater detail. Today, we will hear more, and I don't expect it will be reassuring. The question is, what can we do about it? We have to decide whether, or how, the National Science Foundation, with its small budget, can make any dent in a problem of such large dimensions.

In my view, there is something we can do. The Science Foundation is geared to promoting quality, quality in its research and quality in the development of new technological ideas.

That mission to promote quality has paid off in the past. We have achieved a position of preeminence in science, as we have in other fields of endeavor. Foreign students come here for the best training available anywhere in the world. We are still the leaders in a number of important fields, including biogenetics, electronics, and computer sciences. If our ability to develop technology, or to train our youth in how to use it, is slipping, it seems to me that we have the will and the resourses to correct that.

Last week, Dr. Carl Sagan, astronomer, teacher, and well-known to most of us through his television series, "Cosmos", put the issues very simply: We live in a society that is clearly dominated by science and technology. Our national survival, and perhaps even our survival as mankind, may well depend on how well we understand and use the tools and the products of science. Our short-term decisions must be made, therefore, with that long-term truth in mind.

In my view that is not an exaggeration, and most of my colleagues agree, at least in principle. That is why we regard the National Science Foundation as such an important Federal agency, and why we have chosen to devote extra time to reviewing the issues of science and engineering education.

We have with us today a number of knowledgeable witnesses whose testimony will help us to put the programs of the National Science Foundation into appropriate perspective. I would like to welcome each of you, and thank you for coming.

At this point we have no opening statement from the minority. Mr. Brown, anything further?

Mr. **Brown**. No, thank you.

Mr. **Walgren**. Well, with that I want to welcome the witnesses from the National Science Foundation in the first panel, Dr. John Slaughter, the Director of the National Science Foundation, accompanied by Dr. Don Langenberg, who is the Deputy Director of the Foundation, along with Dr. Walter Gillespie, the Acting Assistant Director of Science and Engineering Education in the Foundation.

I understand Dr. Gillespie is accompanied by Dr. John Hogness, a member of the National Science Board and Hon. Richard Hays, the Acting Assistant Secretary for Educational Research and Improvements of the Department of Education. Mr. Hays is accompanied by Dr. Arthur Melmed of the National Institute of Education. It seems like an unwieldy panel. Just so those of you who want to contribute to this panel are at the table. That is all that counts.

Dr. Slaughter, please proceed as you feel is best.

STATEMENT OF DR. JOHN SLAUGHTER, DIRECTOR, NATIONAL SCIENCE FOUNDATION, ACCOMPANIED BY DR. DONALD LANGENBERG, DEPUTY DIRECTOR, NATIONAL SCIENCE FOUNDATION, AND DR. WALTER GILLESPIE, ACTING ASSISTANT DIRECTOR, SCIENCE AND ENGINEERING EDUCATION, NATIONAL SCIENCE FOUNDATION, WITH DR. JOHN HOGNESS, MEMBER, NATIONAL SCIENCE BOARD, AND HON. RICHARD W. HAYS, ACTING ASSISTANT SECRETARY FOR EDUCATIONAL RESEARCH AND IMPROVEMENTS, DEPARTMENT OF EDUCATION, ACCOMPANIED BY DR. ARTHUR MELMED, NATIONAL INSTITUTE OF EDUCATION

Dr. **Slaughter**. Thank you, Mr. Chairman.

Mr. Brown, Mr. Weber. We are pleased to be here this morning to discuss our programs in science and engineering education.

You have already mentioned some of the persons who are accompanying me. I would like to introduce formally Dr. John Hogness, who is on my left; he is president of the Association of Academic Health Centers and president emeritus of the University of Washington. As a member of the National Science Board, Dr. Hogness is involved in the Board's planning and policy development of NSF's programs in science and engineering education.

On my right is Dr. Donald Langenberg, Deputy Director of the National Science Foundation. And Dr. Walter Gillespie, who is sitting behind me and to my right, is the Acting Assistant Director of Science and Engineering Education at NSF.

Mr. Chairman, with your permission, I have a brief statement that I would like to read if I may. It will not take long. I think it best describes the position of the National Science Foundation on this important topic.

The administration's proposed budget for the National Science Foundation, delivered to the Congress today, recommends the termination of all science education programs in fiscal year 1982. The only exception is a request for $9.9 million to continue support for the second and third years of fellowships awarded in prior years.

As this committee is well aware, the Foundation has operated a broad range of science education programs for many years. Although in recent years funding for these programs has declined both absolutely and relative to research funding, in fiscal year 1981 we are still supporting school and college teacher development, fellowships for graduate students, special programs for minorities and women, equipment purchase and course improvement, and research and information programs.

Why should funding for science and engineering education be eliminated now? The reason is the obvious one: the overriding need to reduce Government expenditures. The President has set strict spending targets, which must be met if the goals of his program of economic recovery are to be achieved. Along with many other agencies, the Foundation has been confronted with hard but necessary decisions concerning which programs have first priority, and which programs must be reduced or eliminated.

In this difficult situation, we believe that insuring U.S. scientific strength through research in the major fields of science and engineering is the overriding priority. The production of new knowledge is the foundation on which our national security and economic vitality rests, and we dare not reduce it. Given the hard choices which the administration has had to make, I believe the only proper course is to concentrate on the research activities of the Foundation, and reduce or eliminate those other activities that, however desirable, do not directly and immediately serve this purpose.

As you know, Mr. Chairman, the Federal Government is the primary source of funds for basic research, providing about $5 billion each year to support about 70 percent of all basic research performed in the Nation. National Science Foundation programs account for about one-fifth of all Federal support for basic research. On the other hand, the support of education comes from a variety of sources, primarily at the State and local levels. Our Nation invests each year on education over $140 billion, of which NSF's traditional investment in the neighborhood of $80 million annually is a small part. Therefore, we believe that national interests will be better served by the elimination of these science education programs than by an equivalent reduction in the Foundation's research programs.

The mission of the Foundation continues to be, as this committee is well aware, the support of both research and education, balancing them so that the health of science and engineering is maximized. In the 1960's, we concentrated on science curriculum development, on teacher training, and on the development of scientific manpower. There was tremendous leverage in these efforts; for relatively small amounts of money, we had a profound influence on precollege science education across the entire Nation, and the number of scientists trained rose markedly. In the 1970's, however, this effort became somewhat more diffuse, with many relatively small programs. It can be argued that not one of these is of a size sufficient to deal effectively with the problem it addresses. In this situation it is good judgment to preserve the research programs, which we know are effective, and take the needed reductions in the science education programs.

I believe that the economic climate of the country will improve markedly in the next few years. When that occurs, and when the budgetary atmosphere is less restrained, we can consider strengthening efforts to encourage excellence in science and engineering education. The Foundation and the Department of Education have recently completed a report "Science and Engineering Education for the 1980's and Beyond" which suggests some of the things that need to be done. The National Science Board is also considering how we might best proceed. A white paper is in preparation, and the Foundation's education programs will be a principal issue for consideration at the long-range planning meeting of the Board in June.

I would also like to point out that some of our important science and engineering education goals will continue to be served, at least in part, by the research programs. In recent years, more than 90 percent of the graduate student support provided by the Foundation has been in the form of research assistantships on regular research grants, rather than fellowships. This support will continue essentially unchanged. In the conduct of these research programs, we will also pay special attention to the participation of women and minorities. The support of scientific research in academic institutions also contributes in a number of ways to excellence in science and engineering education. We believe that the Foundation's support of research will continue to strengthen the melding of teaching and research that is a tradition in our research universities.

We can do all these things, but the fact remains that we have had to make a choice. No one likes that—I assure you that I like it least of all—but I believe we have made it correctly. I strongly urge this committee to sustain the priorities of the administration and the funding levels proposed in the revised budgets for 1981 and 1982.

Thank you, Mr. Chairman. I and my colleagues will be happy to respond to any questions that the committee may have.

Mr. WALGREN. At this point I would like to continue with opening statements of any other member of the panel. I understand Mr. Hays has a statement.

STATEMENT OF RICHARD W. HAYS, ACTING ASSISTANT SECRETARY FOR EDUCATIONAL RESEARCH AND IMPROVEMENT, DEPARTMENT OF EDUCATION

Mr. HAYS. Yes, I do, Mr. Chairman.

With your permission, I would like to read that opening statement. It is very brief.

Also, I would like to make sure that I have acknowledged the presence of Dr. Melmed, who is the Adviser on Science Education Matters to the Office of Educational Research and Improvement.

Mr. Chairman, members of the subcommittee, I thank you very much for extending an invitation to the Department of Education to appear before your subcommittee today. Given the purpose of today's hearing, I believe it is appropriate that my comments be directed to the relationship between the Department of Education and the National Science Foundation (NSF).

As you know, the Department of Education Organization Act requires that the Department and the Foundation coordinate their efforts to improve the quality of science, engineering, and mathematics education. This mandate formalizes and strengthens a relationship which has existed for many years. With the establishment of the Department, the organizational focus of this relationship rests in the Office of the Assistant Secretary for Educational Research and Improvement, an office which has the requisite charge and many of the components necessary for joint efforts with the Foundation. Permit me to cite some examples which will illustrate the coordination between the two agencies.

The National Institute of Education (NIE) supports a number of research and development programs in mathematics education. Presently, there is a joint NIE-NSF program to improve school mathematics instruction through the use of new information handling technology. The primary emphasis of the program is on the development of prototypes for relevant instructional courseware and methods of assessing student progress. Two concerns guide the development and operation of this program: (1) insuring that new information technologies reduce inequities in educational performance, and (2) assuring the successful adaptation of new technologies in the classroom.

The Department collaborates with NSF on the preparation of the annual report and Five-Year Outlook on Science and Technology. This year our contribution to the Five-Year Outlook focused on cognitive science, organizational science and information technology and their effect on the improvement of school practice.

There are continued working relationships between the Foundation, the National Center for Education Statistics (NCES) and the National Institute of Education in sharing and reviewing statistical and informational data.

The Department has ongoing communication with the Foundation on the two programs transferred to the Department by the Department of Education Organization Act: Precollege teacher development in science program, and the minority institutions science improvement program (MISIP).

Perhaps the most visible project is our collaborative effort in preparing the report "Science and Engineering Education for the 1980's and Beyond." A spin-off of this effort is a number of select, joint activities to increase public awareness of the report and the need for excellence in science and technology. Presently, the agencies are supporting several regional conferences with educators, scientists, leaders from business and industry and State and local officials to discuss what activities might take place in order to improve the understanding of science and technology among all Americans, both in and out of school.

The issues raised in the report, particularly those which relate to elementary and secondary education, will be examined by the Department over the next few months as it etches out its role in support of education.

In a speech given to the National Association of School Administrators, Secretary Bell emphasized the recent neglect of quality education and our loss of momentum from the post-Sputnik emphasis on mathematics, biology and chemistry. The Secretary issued a challenge to students urging them to achieve competence in mathematics, in science, and in English composition as the indispensable means of developing a disciplined mind and as a capacity for further learning and advancement in today's world. Within the Department's Office of Educational Research and Improvement, a number of programs exist which will enable schools to have better information at their disposal to aid them in addressing problems in science and math education. The National Institute of Education will continue its work in mathematics education and the use of electronic technologies in the schools. Through the Fund for the Improvement of Postsecondary Education (FIPSE) and the minority institutions science improvement program, postsecondary institutions are increasing their capabilities in science instruction and education. The National Diffusion Network (NDN) will continue to encourage and assist local education agencies in adopting up-to-date, effective programs.

Mr. Chairman, I have discussed this morning some of the activities which the Department has undertaken with the National Science Foundation. Most of the projects, such as the Report on Science and Technology, the 5-Year Outlook and the annual report involved our interaction with the agency as a whole. We would expect that relationship to continue. The present economic crisis requires our making some very difficult choices on the funding of programs. This administration has made those choices and would urge you to support its proposals for the coming year.

Thank you for the opportunity to speak to you today. Dr. Melmed and I will be pleased to respond to any questions you may have.

Mr. WALGREN. Thank you, Mr. Hays.

Dr. Hogness, do you have a statement that you would like to contribute at this point?

Dr. HOGNESS. No, I do not.

Mr. WALGREN. Let me say that any of the statements you would like to expand on later could be incorporated in the record. So if there are observations that you would like to add, please feel free to submit them to the committee and we would include them in the record if it are proper and helpful.

First I would like to lead by asking Dr. Slaughter a little bit about the process of selecting the target of science and education and the various cuts that I understand are across several of the Science Foundation functions. I guess what I am most interested in is where did these cuts originate and what was the thought process that went into the targeting of the reductions. It is my understanding that the process for developing a budget for fiscal year 1982 would start sometime last summer with the Foundation completing a review along with the National Science Board and generating some budget suggestions that would then be made to the administration. Is that correct?

Dr. SLAUGHTER. Mr. Chairman, the process is a long, complicated one, involving the Board, Foundation staff, and the Office of Management and Budget. I would like to ask Dr. Langenberg, who was involved in the earlier activities before I arrived at the Foundation as Director, to gives you the complete background.

Dr. LANGENBERG. Thank you, Mr. Chairman.

The process of developing the Foundation's zero-base budget proposal to the Office of Management and Budget began in earnest for fiscal 1982 in early summer of last year, 1980. If one includes the prior long-range planning process through which the Foundation and the National Science Board go each year, then that process can be said to have begun sometime in late 1979. The long-range planning process through which the National Science Board goes each year results, in about April, in a general set of policy guidelines which are then applied to the development of the specific detailed zero-based budget during the following summer.

Mr. WALGREN. And then the following summer you develop a zero-based budget package, and that is then sent to the administration and particularly to the Office of Management and Budget. Is that correct?

Dr. LANGENBERG. That is correct.

Mr. WALGREN. And that zero-based budget would have a number of different priorities in it. It would indicate priorities that the Foundation felt at that time—and we are talking about last summer—would be the appropriate ones to follow for fiscal year 1982.

Dr. LANGENBERG. Yes, sir, that's correct.

Mr. WALGREN. Then there would follow a period of consultations with OMB during the fall about the zero-based budget and the priorities reflected therein.

Dr. LANGENBERG. That is also correct, sir. That period includes providing responses to requests for further information from OMB on specific matters in the budget. And there is a significant amount of discussion back and forth all through the fall.

Mr. WALGREN. And this process then resulted in the budget that was presented to the Congress in January known as the Carter budget.

Dr. LANGENBERG. That's correct.

Mr. WALGREN. The last submission by the Carter administration. And that differed substantially from the budget that we now are being presented with by the new administration. Now, then, the question comes: What was the Science Foundation's contact with the new administration that led to these changes in the budget that you developed last summer and fall? At what point was NSF consulted with respect to the new administration's budget?

Dr. LANGENBERG. The first contact that we had with the Office of Management and Budget on specific elements of the fiscal year 1982 budget revisions occurred in mid-February, I think on the 11th.

Mr. **Walgren**. You say you were contacted on the 11th of February?

Dr. **Langenberg**. I believe so, yes.

Mr. **Walgren**. And when you were contacted by the administration, what did they present you with at that point? Did they say we want to reduce the budget, therefore please give us some suggestions? Or what did the administration ask of you on the 11th? Or did they ask anything of you?

Dr. **Langenberg**. We were presented with some proposed reductions which affected particular major portions of the budget. We were asked to respond with counterproposals and additional information—whatever we felt would be an appropriate response to those proposals.

Mr. **Walgren**. And how much time were you given to come back to them with that developed reponse?

Dr. **Langenberg**. It was suggested that it would be most convenient if the response could be received during the following day.

Mr. **Walgren**. During when?

Dr. **Langenberg**. The following day.

Mr. **Walgren**. The following day?

Dr. **Langenberg**. Yes, sir.

Mr. **Walgren**. And when were you able to respond?

Dr. **Langenberg**. We responded during the following day.

Mr. **Walgren**. You responded during the following day. Was the Science Board at all involved in the process of that response?

Dr. **Langenberg**. No, sir. Board members were informed of the result of that process during their meeting, which happened to take place during the following week.

Mr. **Walgren**. And when you say you were asked to respond to the budget given you by OMB, or the suggestions given you by OMB—was there an ability to change the allocations or be flexible in your response, or because of the nature of the programs was there just not any substantially different suggestion that could be made?

Dr. **Langenberg**. There was some opportunity to suggest changes within broad categories of the proposed reductions, and we did so.

Mr. **Walgren**. And where would those opportunities have been found? In which broad categories could you have made changes?

Dr. **Langenberg**. The principal major categories in which reductions were proposed at that time included the cross-directorate programs, many of them new starts; the science and engineering education programs; the behavioral, social and economic sciences; and certain programs within our directorate for Scientific, Technological and International Affairs.

Within the latter three major areas, there has been some flexibility to determine just where the reductions would take place and how; that is to say, within the Science and Engineering Education Directorate, within the Behavioral and Social Sciences, and within the Scientific Technological and International Affairs Directorate.

Mr. **Walgren**. So at that point the cross-directorate was zeroed out?

Dr. **Langenberg**. That's correct.

Mr. Walgren. And so there would be no flexibility there whatsoever. A zero is a zero.

Dr. Langenberg. Yes, sir.

Mr. Walgren. But you feel that you were given some maintenance of financial commitment to Science and Engineering Education and the behavorial and social and economic areas.

Dr. Langenberg. Yes, sir. At that stage.

Mr. Walgren. OK. That was the first stage. And then there was a second position taken by OMB which reduced that flexibility even further.

Dr. Langenberg. Yes, sir.

Mr. Walgren. And how did it reduce that flexibility?

Dr. Langenberg. During the second stage, there was a further reduction in Science and Engineering Education and reductions in the four research directorates.

Mr. Walgren. And at that point, when we say there was a further reduction in science education, it was essentially reduced to only meeting some traineeship commitments that were in fact in place from the previous year.

Dr. Langenberg. That's correct.

Mr. Walgren. And the whole rest of the function was zeroed out.

Dr. Langenberg. Yes, sir.

Mr. Walgren. And this all at a time when there was, to the best of your knowledge, little advice received by the administration from the National Science Foundation particularly except for those 3 days.

In other words, you were essentially responding to initiatives taken by the administration. There was not a consultative process going on at that point.

Dr. Langenberg. We were responding to proposals made by the administration.

Mr. Walgren. And this also at a time when the administration, at least in visible part, had no science policy advisor to the President and no built-in administrative advice from the science community.

Dr. Langenberg. I don't know what kinds of advice may have been available to our budget examiners and other administration officials within the Office of Management and Budget. I am not aware that a Director of the Office of Science and Technology Policy and Science Adviser to the President has as yet been named.

Mr. Walgren. The reason I wanted to try to develop that was that certainly in my own view, the changes from the Carter budget to the Reagan budget have got to be weighed in view of the input into them. And I am very concerned that decisions might be made which really left the National Science Foundation no flexibility to maintain efforts in areas which from the scientific viewpoint may be extremely critical. Yet these may not rise to the level of attention in OMB, which is not necessarily sensitive to those same concerns.

It also concerns me that the time frame in which these changes were presented by external fiat to the Foundation, was a time frame which really allowed for no response whatsoever from the Science Board. And as I understand it, we do rely on the Science

Board to be part of the mix in the advice that we hope will be developed by the National Science Foundation programs. And that is one of the reasons why that Board is an independent board, a board appointed for a term certain. Was the Science Board ever involved in responding to OMB's really absolute cuts?

Dr. Hogness?

Dr. HOGNESS. First of all, let me say that the National Science Board is ordinarily very heavily involved in the budget process. However, the National Science Board per se was not involved in response to these two cuts. I believe that the Director kept the Chairman of the Board informed, and there may have been some conversation there, but otherwise the Board was not involved. I suppose given the apparent necessity for rapid action, since the Board meets only once a month that is not entirely surprising.

Mr. WALGREN. Have you ever in your experience with the Board been presented with such a major change in the direction that the NSF was previously going with no opportunity to comment on it whatsoever?

Dr. HOGNESS. No, I do not believe so. On the other hand, there has not been an apparent need for rapid action expressed in the same way, at least in my experience.

Mr. WALGREN. I would like to turn to the other members. I feel we ought to proceed in turn as members arrive, so with the minority's forbearance, let me turn first to Mr. Brown.

Mr. BROWN. Thank you, Mr. Chairman.

Mr. Hays, you have undoubtedly in the Department of Education gone through a somewhat similar process as in the NSF. Could you give us just a thumbnail sketch of what happened to the programs within your jurisdiction?

Mr. HAYS. The process that my colleague described is similar to the process that the Department of Education has gone through. In fact, last week we testified before the Senate Appropriations Committee on the past administration's fiscal year 1982 budget. Our revised budget will be released at 2:30 today. The basic changes and reductions in our budget were outlined in the seven fact sheets based on the President's economic recovery plan. The major shift in the budget would be in the consolidation of a number of existing elementary and secondary education programs into block grants to give State and local education agencies greater flexibility to meet their specific educational needs.

Mr. BROWN. The information that I have, which is, of course, largely newspaper reports, indicated that this consolidation process involved an overall reduction of about 25 percent. Is that roughly correct?

Mr. HAYS. That is my understanding, sir.

Mr. BROWN. About the same order of magnitude as the NSF submission. That is, the Carter submission versus the revised Reagan submission.

Mr. HAYS. I am not familiar with the total NSF budget. With respect to the Department of Education's budget I believe Secretary Bell, in his negotiations with OMB, made sure that we took our fair share and, that it was equitably and reasonably distributed throughout the entire department. Hopefully, with the consolidation approach, we would reduce the overhead cost and perhaps that reduction would not be as significant as it would first appear.

Mr. **Brown**. We certainly hope that that is the case.

Did the programs directly within your purview as Acting Assistant Secretary for Educational Research and Improvement come out about the same as the rest of the Department in terms of reduction?

Mr. **Hays**. I have not seen the overall departmental budget sir, but my understanding is that the Office of Educational Research and Improvement was treated fairly and equitably.

Mr. **Brown**. It was treated fairly and equitably.

Mr. **Hays**. Yes, sir.

Mr. **Brown**. That is fairly and equitably, not fairly inequitably. [Laughter.]

Mr. **Brown**. Now, Dr. Slaughter, in your statement you point to the heydays of the 1960's when we made tremendous impact upon the science education structure of the country with the various programs within the National Science Foundation. Then you make the argument that as these were reduced during the 1970's, they were not of a size sufficient to deal effectively with the problems being addressed. Am I reading you correctly?

Dr. **Slaughter**. That's correct, Mr. Brown.

Mr. **Brown**. Well, that is the argument we made here in the committee.

Dr. **Slaughter**. We are agreed on that point.

Mr. **Brown**. Yes. Well, we will remember that in the future. Looking at the overall picture, my information is that in the other advanced industrial countries, including both our friends and those that aren't so friendly, we have a situation—take the U.S.S.R. as an example—where somewhere between three and six times as large a percentage as of our college-trained students go into engineering and science. This is similar in Japan and the Western European countries to some extent. Is that roughly correct?

Dr. **Slaughter**. I believe so.

Mr. **Brown**. And that this greater emphasis on science and technology in these countries is one of the reasons that we are so fearful that our both economic and military posture may be deteriorating at this time. Is that correct?

Dr. **Slaughter**. Yes, sir.

Mr. **Brown**. Is there any overall strategy that you know of in this administration or the Foundation to redress that situation?

Dr. **Hogness**. May I comment on that, Mr. Brown?

Mr. **Brown**. Certainly. I would be happy to have you comment.

Dr. **Hogness**. I am speaking now as the chairman of a subcommittee of the National Science Board on science and engineering education. We, as the board, became concerned about these very issues that you are talking about almost a year ago. I believe the board was concerned before that, but became more acutely concerned about a year ago. In the June 1980 session of the board, a planning session, one of the major areas of discussion was science and engineering education. Subsequently, the board appointed a subcommittee which I chair to look into these issues. We were concerned not only about our national stature and our educational programs in science and engineering, but also about the board's position, what the board might do to support more effectively those programs in science and engineering education where it was best qualified to do so and perhaps not support those where it was less qualified. That subcommittee is still meeting. It has not submitted its report to the board, but should do so in a month or two. That does indicate, I believe, the planning and the concern of the board over these issues.

Mr. BROWN. Well, I don't want to belittle our great educational system. I think it is one of the strengths of our society. But it is quite obvious in some of the speeches which he has made and which you quote, Mr. Hays, that Secretary Bell apparently is aware of the problem of neglected scientific and engineering education and the salutary effect of the invigoration of that program after Sputnik in helping us to regain some of the momentum that we had lost. The report that was issued jointly by NSF and the Department of Education made these points fairly strongly. And what I am trying to get at is what are the underlying assumptions of this administration as to what we do about this? Is it assumed that the present drives within our system of education will bring about a correction of the problems which exist, without Federal intervention?

Dr. SLAUGHTER. Mr. Brown, one of the problems we are facing right now is that the Office of Science and Technology Policy has not, as Dr. Langenberg said, been fully staffed, and no science adviser has had the opportunity to examine those issues. The administration's posture for addressing these critical areas of science and engineering education and their role in helping this country move forward in productivity and innovation will largely be clarified through the joint planning efforts led by that office.

Mr. BROWN. Well, it is not difficult to understand the basis for the initial budgetary cut that we have seen here. The programs which have been cut are the ones which have been subjected to the most criticism by many individuals over the last few years. I am thinking of the biological, social and behavioral sciences program, and obviously new programs, new starts were cut. And of course there has always been a large minority feeling within the political community that the Federal Government should not have a large role in the support of education anyway. And these cuts reflect that general philosophy. I think the Foundation is to be commended for their rapid reaction to this new philosophical thrust. It belies the criticism that the bureaucracy can't be responsive. We appreciate that very much. It is just a question of what they are being responsive to.

I think I will yield at this time, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Brown.

Mr. Weber?

Mr. WEBER. Dr. Slaughter, the general discussion we seem to be having here is over the priorities that the administration set forth. Especially in view of the fact that we know pretty much what direction the administration wants to take on the Department of Education, I wonder if you can tell me generally how you think the administration views the role of the National Science Foundation for the long term.

Dr. SLAUGHTER. Yes, Mr. Weber. I believe very strongly that the administration sees the support of quality science in the major research areas as the current and continuing responsibility of the National Science Foundation. I believe that the administration is committed to supporting those programs which are most likely to contribute to economic recovery program.

Mr. WEBER. You believe that the administration does believe that is the proper role of Government, to maintain that kind of involvement?

Dr. SLAUGHTER. Yes; I do.

Mr. WEBER. In view of that, and in view of the fact that we also know something about the philosophical drift as far as the Department of Education goes, wouldn't it have made somewhat more sense to have taken some of the dollars out of the Department of Education's budget and maintain the science education funding within the NSF budget, since it would appear that the administration intends to phase out the Department of Education—at least they have been talking in that direction for some time, and the NSF has a proven record of success in science education. As you have been presenting it to us, wouldn't it have made more sense to maintain the dollars there and find some way of taking them out of what might be a rather short-lived Department of Education?

Dr. SLAUGHTER. Mr. Weber, I am not in a position to respond directly.

Mr. WALGREN. Mr. Hays, can you respond to that?

Mr. HAYS. I prefer not to, Mr. Weber, but I will say I have been involved in those types of discussions. But I would just like to indicate that I do not believe it is the administration's plan to do away with the Department of Education, but rather to deescalate its status. And those options are being considered by the Secretary and obviously will be discussed with the President. I think in the deliberations that have gone on with the Office of Management and Budget and to maintain the Federal responsibilities as it relates to education, those have been done very carefully, and those assessments have been made.

As to transfers between agencies, I really am not prepared to discuss that.

Mr. WEBER. Shifting ground just a little bit, can you give me some kind of an overview of what is the thrust of other agencies of Government in terms of the areas of basic research? We talked a little bit about the impact of the Department of Education on science education. It seems to me there are of course other areas of Government where other departments have an impact on basic research as well. Can you sort of review that for me, what the extent of that and the magnitude of that might be?

Dr. SLAUGHTER. I can make only some broad and general statements, inasmuch as I have not had the opportunity to see the administration's budget for other agencies. I would say only that the National Science Board and the Foundation believe that what we refer to as the pluralistic support of basic research is important. Therefore, we have encouraged strong research budgets in the Departments of Defense, Energy, of Agriculture, and Commerce, particularly in areas directly related to the missions of those agencies. We also believe the National Science Foundation's broad support of basic research, when joined with the more mission-oriented research, provides the country a stronger research support base. We anticipate that these joint efforts will continue.

Mr. **Weber**. I don't want to nit-pick you on your priorities, but I would like you to address this a little more. The administration, although it is calling for a reduction in the Carter budget levels for basic research, actually does call for an increase in basic research funding within the NSF's budget. I presume that other departments of government also have a substantial or meaningful commitment to basic research within their budget. Would you explain to me a little bit your thinking in terms of priorities. Wouldn't it make more sense to try and salvage some of the science education budget, even if it is at the expense of part of the basic research budget; rather than scrapping the entire commitment, basically?

Dr. **Slaughter**. Mr. Weber, whenever you are faced with this kind of stringent budgetary situation, you have really only two choices: one is trying to spread the impact by taking a lesser amount from a larger number of locations. The other is attempting to make some hard-headed management decisions and identify priorities. The administration has chosen the latter approach. It has clearly identified the budgetary priorities that show the greater support for the physical sciences and the life sciences. And at this time it is necessary that support in the other areas be deferred or reduced. That is why the science and engineering education programs are not supported at the same levels as the basic research programs.

Dr. **Langenberg**. Mr. Weber, the Foundation tries to avoid overlap and duplication with the research programs of other agencies. In some fields of science and engineering, the Foundation is the dominant Federal source, indeed the dominant national source for research of a more fundamental sort. In other fields NSF is a relatively minor participant. In the former category I would put ground-based astronomy, for example, or mathematics; in the latter category, some of the fields related to biomedical research. The National Institutes of Health, as you know, invests something between two and three times the NSF budget in biomedical and health research. We see to it that the research which NSF funds in the biological sciences avoids programs in areas directly funded in a major way by NIH. The result is that National Science Foundation programs are not in many respects similar to those of the mission agencies. We have a legislative mandate to cover all fields of science and engineering; the mission agencies are constrained to support research in areas perceived to be relevant to their missions. That means that NSF covers a good many fields not covered by other agencies. It sometimes means that we are playing the role of a precursor or a scout, if you like, exploring new areas so new that they have not yet been perceived as relevant to the mission of a particular mission agency.

Mr. **Weber**. I appreciate that, Doctor, but my point is that while there are other areas of Government that are investing in basic research, and I appreciate your point, there are basically no other agencies of Government that are investing in basic science education, except the relatively minor programs we have heard about in the Department of Education. Is that correct?

Dr. **Langenberg**. In the most direct sense I believe that is correct.

Mr. **Weber**. I just have one final question that refers to some of the points that have been made about the consulting process back and forth between OMB, the National Science Foundation and the Science Board and the fact that perhaps there was not sufficient consultation on the part of OMB. You know, we had a lot of warning about budget cuts coming. Could you not have convened a special meeting of the Science Board and taken it on yourself to try and impact the administration's thinking?

Dr. **Slaughter**. Certainly when you look back at things, you can identify a number of paths that might have been taken. It was our view, Mr. Weber, that the best approach was to put together the strongest program in the areas for which we have statutory responsibility so that we could respond to administration requests or initiatives. And that is the path we took. The Board and the Foundation in the process outlined by Dr. Langenberg had, we believed, developed in all of our areas an optimum program. And the zero-based budgeting process still stood up as the best way for us to interact with the administration in reshaping our program.

Mr. **Weber**. Was there a conscious decision on your part not to try to pursue more aggressive means of lobbying the administration or the OMB in terms of impacting the final budget recommendations?

Dr. **Slaughter**. Yes, sir.

Mr. **Weber**. Thank you. I have no further questions, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Weber.

Mr. Dymally.

Mr. **Dymally**. Mr. Chairman and members of the panel.

Is it correct to say that science and engineering education is part of the statutory mission of NSF?

Dr. **Slaughter**. Yes, sir.

Mr. **Dymally**. Then it will take more than budgetary cuts to eliminate that mission, isn't that correct also?

Dr. **Slaughter**. That is correct.

Mr. **Dymally**. What impact will these cuts have on the community colleges in the field of science and engineering education?

Dr. **Langenberg**. The principal programs available to support efforts in community colleges are managed within the Science and Engineering Education Directorate. If the budget for that directorate is not maintained, those programs will vanish along with the others in the directorate.

Mr. **Dymally**. And finally, Mr. Chairman, I have already drafted a letter to Mr. Stockman about these cuts because I believe they are going to have a very detrimental effect on the community college education.

Mr. **Walgren**. Would you like to have that letter included in the record as part of our hearing?

Mr. **Dymally**. Indeed, sir.

Mr. **Walgren**. We would appreciate that.

[The letter mentioned above follows:]

MERVYN M. DYMALLY
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Congreſs of the United States
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Washington, D.C. 20515

March 10, 1981

David Stockman, Director
Office of Management and Budget
Old Executive Office Building, Room 252
Washington, D.C. 20503

Dear Mr. Stockman:

There is no dispute that this country is experiencing a critical shortage of scientists and engineers. Every phase of society has become increasingly dependent on science and engineering education.

Cutting National Science Foundation funds in these areas would be counterproductive, to say the least, and will do irreparable damage to them at a time when they are badly in need of financial assistance if we are to develop our resources and remain competitive with the other technologically industrial countries in the world.

If there is to be an honest and sincere effort to increase the participation of women and minorities, and to the NSF and those institutions of higher learning, then funds for our scientists and engineers must not be decreased.

The private sector cannot be expected to bear the entire burden of insuring that this nation slides no further down the pole of science and engineering and becomes a confirmed second rate power in those areas. In recent years, science and engineering has not been given the priority that it so urgently deserves if there is to be a reversal in the trend of scientific and technological illiteracy. There has to be a combination of efforts by the Federal government, the private sector and academics through such organizations as the NSF.

It is a dangerous course that we will be charting if these proposed budget cuts become a reality. Not only will it deprive us of realizing our potentials in the various science and technological disciplines, but it will tip the scales against our interest and threaten our very security in an increasingly unstable and hostile world.

Respectfully,

MERVYN M. DYMALLY
Member of Congress

Mr. **Walgren**. Mr. Shamansky.

Mr. **Shamansky**. Thank you, Mr. Chairman.

Dr. Slaughter, I will start off with a very parochial approach to this thing. Ohio State, Battelle Institute and Chemical Abstracts are all located in my home community, and I believe that they must have a supply of trained engineers and scientists. Regarding your planning—the message I got from you is you would rather have, under the constraints you are operating, no program than some program. How long do you estimate our country can continue, in my opinion, to neglect the kind of scientific and technological education that I believe we have to have? If the Government doesn't do any of these things, have you estimated at what point we will be at a serious disadvantage vis-a-vis our international competitors? Have you examined that question?

Dr. **Hogness**. May I try to respond or begin a response to that? First of all, one of the reasons the Board did take action to review science and engineering education programs was because of a concern over a present shortage of at least computer scientists and engineers in this country, particularly of university faculty members in the fields of engineering and computer sciences. However, I should again point out that, although the science and engineering education budget is reduced to essentially zero, it does not mean that the Foundation is not supporting the education of scientists. It does that, as Dr. Slaughter pointed out, to some degree through its standard research grants.

I think we are in difficulty. I think this may be a short-term problem as far as the engineers and the computer scientists are concerned. Certainly by comparison with other countries, we are lagging behind. To try to identify any point where we would have a crisis rather than a serious problem, I do not know how to do that. But I do think at the present time things are not getting any better.

Mr. **Shamansky**. I am fascinated by the use of the expression short-term problem. Why is it short term?

Dr. **Hogness**. I am talking about engineering and computer science. My impression is that we could, by increasing support for training of those individuals, bring up the number in a relatively short period of years. I meant to contrast that with the long-range problem of science and engineering education in our primary and secondary schools, which is a longer term issue.

Mr. **Shamansky**. This is frankly the area of my major concern, because it seems to me that we are simply mortgaging our future in the most inane fashion. That is a bias I bring to this question. Now, if I may go on, the Secretary of Energy testified before our committee recently expressing his great faith in the market to take care of developing energy. I would like to ask you to comment. Do you see any possibility that the market, whatever that magical thing is, will repair whatever damage we might have in preparing students for the kind of scientific and technological education they have to have? And how would that be done?

Dr. **Slaughter**. Mr. Shamansky, I feel strongly that there is a role for the private sector in the immediate issue of how we address the problems of a shortage of highly qualified engineers and computer scientists to fill positions in industry and in universities.

I do believe, however, that that will happen only if an innovative program organized under the auspices of the proper agencies, including the National Science Foundation, makes it possible for the private sector to see the benefits of such a program. It will not happen in a vacuum, and it will require the involvement of the Department of Education, the National Science Foundation, and the mission agencies with an interest in the existence of a qualified cadre of engineers and computer scientists.

Mr. **Shamansky**. Would it not be more likely that the market would pick up research in the hard sciences than in the education of secondary students and college students?

Dr. **Slaughter**. The likelihood is probably about the same, inasmuch as research in the hard sciences is research with exceedingly high risks. Oftentimes the cost of conducting the research and of buying the facilities and instrumentation is too high. It is difficult for a private company to make that kind of an investment. So there are long-term consequences for much of the knowledge-oriented scientific research supported by the National Science Foundation—the same sorts of long-term consequences associated with the education of secondary school students.

Mr. **Shamansky**. In my own mind I cannot imagine any kind of reasonable equating of the two. Clearly the risk involved in trying to train high school students and college students is very, very long range. I can't imagine any corporation systematically adopting that. Would you care to comment on that? Is there any reason to think there is a better chance that they would fund high school, secondary, and college education as distinguished from hard science?

Dr. **Slaughter**. No. When I was talking about the role of the private sector you recall I was talking primarily about the problem of education in the engineering and computer sciences But the question of how we address the needs for improving the quality of science and mathematics instruction for young people at the precollege level—there I think the private sector would be primarily limited to improvements in technology for instruction. There would not be the kind of investment in the private sector that would solve the problem.

Mr. **Shamansky**. In other words, whatever assistance we had would simply disappear and we take our chances.

Dr. **Slaughter**. Yes, sir.

Mr. **Shamansky**. Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Shamansky.

Mr. Ertel.

Mr. **Ertel**. Thank you, Mr. Chairman.

I am sorry I was late and did not hear all of your testimony and all of what you addressed to the chairman, but I did pick up the "Budget in Brief" I assume you delivered today to the committee. Just paging through this, I looked at the inside cover and it says "What is NSF?" And it says:

> NSF occupies a unique place among Federal Government agencies, with responsibility for the overall health of science instead of research directed to specific missions.

For the overall health of science, and that is what the function of—or what NSF is doing. It is my understanding that you agreed with OMB to the cuts to zero out science education. How can you perform your function looking at the overall health of science and really follow that objective by zeroing out science education, especially in those areas of secondary and elementary education where the health of science for the future is really being developed? I wonder if you could respond to that.

Dr. SLAUGHTER. Mr. Ertel, there are two critical issues here. First of all, the budgetary reductions are severe. It is our opinion that within the basic research budget, the core research programs of the Foundation—the physical sciences, the geophysical sciences, the life sciences—we have the best opportunity for supporting many of the education components of our mission responsibility. For example, even though in our Science and Engineering Education Directorate there was a program for fellowships for graduate students, 90 percent of the support we provide to graduate students at the research universities is provided from the core research funding. In precollege education support, we found a considerable number of programs, each with an excellent purpose, but each operating submarginally, lacking the dollar support necessary to make it a strong program.

In that kind of environment and in the budgetary environment of today, we support the recommendation that those programs not be continued at this time. Instead, we choose to concentrate on the core research budget and make optimum use of those funds to carry out some of NSF's objectives in science education.

Mr. ERTEL. It was just pointed out by a person here following along with my question, that in your earlier submission here talking about what NSF does, it says and I quote, "NSF maintains U. S. scientific strength through the support of research and education in all fields of science and engineering". Now you say NSF maintains U.S. scientific strength through the support of research and related science and engineering grants. Is this a basic restructuring of the NSF? Is that what we are getting through this budget presentation? And second, since I read further down "How is it managed?" It says a 25-member National Science Board establishes policies for the National Science Foundation." Have we had a basic restructuring within the NSF without the Science Board approving or participating in that restructure which it is supposed to do? Second, is there basically a restructuring?

Dr. SLAUGHTER. No, there is no restructuring of the responsibilities of the Foundation. There is no change in our statutory responsibilities. The NSF——

Mr. ERTEL. May I interrupt you, Doctor. I am curious about that statement. We are moved from January of 1981 to March of 1981. That is 2 months. I haven't seen any great upheaval in the United States during tha period of time to change the wording and the mission.

Dr. SLAUGHTER. All I am saying, Mr. Ertel, is that the mission stands as it did in January. The mission of the Foundation is to support research and education; science and engineering education. The act, section 3[a] of the public law establishing the National Science Foundation, says the Foundation is authorized and directed to initiate and support basic scientific research and programs to strengthen scientific potential and science education programs at all levels in the mathematical, physical, biological, medical, social and other sciences. That still stands, and we still believe that is the overriding set of guidelines on which we base our management decisions.

Mr. ERTEL. Doctor, I hate to belabor a point, but I look at these two comparisons within 2 months, I find the second sentence completely the same between the two and what it does, and the first sentence—and I believe I can understand English—conveys to me an entirely different meaning. And it seems to me one doesn't change a publication and change the wording unless one intends something different. And it is not just grammatical changes. Now, would you compare the two and tell me what you really mean by the difference in language?

Dr. SLAUGHTER. Mr. Ertel, I am not convinced that there is really as substantive a difference reflected there as perhaps you feel through your reading. There has been a change in the past 2 months in the sense that a different mandate is expressed by the current administration. We believe that both statements reflect the truth about the National Science Foundation, and I would be comfortable with the preceding statement in the Budget In Brief.

John, do you want to add something?

Dr. HOGNESS. May I add a comment to that, Mr. Ertel, please?

Mr. ERTEL. I would be happy to have you comment on that.

Dr. HOGNESS. Again speaking as a member of the National Science Board, not for the entire Board, although I suspect I might be if they were to be canvassed, I am certain that the Board has no intention whatsoever to eliminate education or ask that the mission of the National Science Foundation be changed to to do so. I think the Board as it works on subsequent budgets will be very concerned about programs in science and engineering education. I for one, and I believe many other members of the Board, will work hard to convince the Board, and after convincing the Board, to convince the administration and the Congress, that there should be a change in policy and that there should be additional support for education through the National Science Foundation in the future.

Mr. ERTEL. Well, maybe if I can just change to one other area, something that is a little more interesting and maybe won't be as controversial. I notice the ocean margin drilling program has very small cuts in the budget that you presented here today, yet it zeroed out science education. Now that is a new program, the ocean margin drilling. We managed to cut some of the money out of that last year which was basically a new program at that time. It is my judgment, and a lot of people vary with it, that that is an exploration for petroleum products basically and it is contributed to by the oil companies. And it has been my view that that belongs in the Department of Energy and not in the National Science Foundation budget. But yet I don't see any major cut in that area, which is really a hard sort of thing, hard engineering practices if you are looking really for petroleum. And I know the standard answer from the National Science Foundation, that you are looking to discover other things, the plate theory of the world and so on. We do have a deep sea drilling program, but a major difference between this program and the deep sea drilling program is this has a blowout provision, which means you are drilling in areas where you expect to hit petroleum-type products, or may hit petroleum-type products. Now, why are we keeping that program, which certainly has some questionable value in my mind, and zeroing out science education? And who made the judgment to zero out science education and to keep that program? Did the National Science Board make that judgment, or did you within the National Science Foundation as the administrators make that judgment? Or did the administration.

Dr. **SLAUGHTER**. Mr. Ertel, you asked a number of questions.

Mr. **ERTEL**. I guess I am just asking who made the judgment?

Dr. **SLAUGHTER**. Let me clarify one point, though, if you don't mind.

Mr. **ERTEL**. Certainly.

Dr. **SLAUGHTER**. I appreciate the interest you have shown in ocean margin drilling. There is a substantive difference between a deep sea drilling project and the ocean margin drilling program. The OMD program will drill in areas where water depths and terrestrial depths are significantly deeper than similar activities in deep sea drilling program by an order of four or five times. A different technology, including, as you mentioned, blowout prevention capabilities is required.

But now to the key issue that you addressed; Who made that decision? The decision was made through the same process that Dr. Langenberg mentioned in discussing the involvement of the Board in the preparation of the zero-based budget and the reaction of the new Office of Management and Budget to our proposals. It was their firm recommendation that the ocean margin drilling program not be reduced.

In fact, as a result of the second proposed reduction, we have taken a 25-percent reduction in the OMD budget. The management of the Foundation removed $4 million from that budget by deferring acquisition of items with long-lead times. I believe that decision was responsive to the reduction recommended by the administration and that we were correct in making those cuts.

Mr. **ERTEL**. I am not quite sure I follow your answer. Did they come back and tell you to zero out science education and to leave the ocean margin drilling program in, and that is what you did?

Dr. **SLAUGHTER**. Yes, sir. The administration suggested that reductions not be taken in the ocean margin drilling program at the same time the proposed numbers for science education were presented to us. We chose at the second wave of reductions to make a 25-percent reduction in ocean margin drilling.

Mr. **ERTEL**. Did they suggest that to you?

Dr. **SLAUGHTER**. No; they did not.

Mr. **ERTEL**. Did the National Science Board agree to all this as the process was going along?

Dr. **HOGNESS**. The National Science Board was not involved in these recent reductions.

Mr. **ERTEL**. I guess the other question I have is since we are in such a crunch for money in the National Science Foundation and the ocean margin drilling program has participation by the oil companies, was there any endeavor made to go back to the oil companies and say, "Hey, oil companies, pony up some more money so we can keep this going and we would like to keep the science education going, so we can transfer some of that money there?"

Dr. SLAUGHTER. No, sir, we have not. We have an operating contract with the oil companies which says that the Federal Government and the participating oil companies will share equally in the costs of the ocean margin drilling program.

Mr. ERTEL. Out of the National Science Foundation budget or the Department of Energy budget?

Dr. SLAUGHTER. The National Science Foundation receives the appropriation for the ocean margin drilling program.

Mr. ERTEL. Well, hopefully we will be able to take a look at that in the authorization legislation here. And I would like to see the contracts which have been signed.

Thank you, Mr. Chairman.

Mr. WALGREN. It strikes me that the administration came to you and said that we will have to not pursue some of our plans because of contractual impossibility imposed by the budget constraints. But they do not go to the oil companies and say that because of contractual impossibility in the Federal budget they are unable to pursue that particular program.

Dr. SLAUGHTER. Mr. Chairman, I think there is some misunderstanding on this point. We determined at the time of the second wave of proposed reductions to reduce the ocean margin drilling program. We, the management of the National Science Foundation. I made that determination with my staff. It was not recommended by the administration.

Mr. WALGREN. But you also made the decision not to pursue a different relationship other than an equal sharing with the oil companies.

Dr. SLAUGHTER. That is correct. In a very short time we did not——

Mr. WALGREN. You are going to maintain that equal sharing effort by the NSF.

Dr. SLAUGHTER. That's correct.

Mr. WALGREN. Let me just ask one other question with respect to maintaining the effort that we are committed to. It is my understanding that we are committed to spending $30 million to promote minorities and women participation in science, and that that is a part of the act, that $30 million shall be available in fiscal year 1981 to carry out the provisions of the minority and women effort in the national science—or through National Science Foundation programs. Are we going to maintain that effort that is directly stated in the act in fiscal year 1981?

Dr. SLAUGHTER. Mr. Chairman, correct me if I am wrong. I believe we have been authorized but not directed, to do that. We fully intend to develop and carry out within the budget a strong program for full participation of minorities and women in science and engineering. We are taking steps now to meet the requirements of the authorizing legislation. By establishing the committee called for, we can begin to put together those programs. It is a matter of personal interest not only to me but also to the members of my staff and the National Science Board.

Mr. WALGREN. I understand that is an area we will pursue further in another hearing.

I have a request from Mr. Brown for a further footnote.

Mr. **Brown**. I asked earlier if there was a strategy or a plan to attack this problem of our relatively poor national posture in science and engineering education. I am looking at it broadly, and I want to put as positive a light on this whole situation as I can. Let me suggest to you the kind of thing that seems to me might be an alternative, recognizing that we have a widely dispersed pluralistic education system and that the Federal Government has become involved in financing aspects of it because of perceived areas of need. In the science and engineering education field it seems that we have the possibility of improving the system substantially if we could convince our major universities and our science-oriented industries to take a real interest in elementary and secondary science education, to create a sense of the excitement of science and engineering as an educational field and as a career. Many industries are doing this. I think of Westinghouse and their science program, for example. And I am wondering if this administration conceivably has or could be persuaded to have a major thrust toward trying to bring about this linkage as a means of enhancing the overall quality of our science and engineering education at every level, from elementary through postsecondary. It would seem to me this would be a positive response to the cutting of the budget. I would like your comments on this, if I may.

Dr. **Slaughter**. I think that is an important point, Mr. Brown. I would like to say something, and perhaps Dr. Hogness would like to add to it with respect to the National Science Board. Yes, I think the administration will be interested in that kind of an approach. And I think that the National Science Foundation has a key responsibility, as Dr. Lewis Branscomb said last week in his presentation and as we are discussing it within the Foundation. We have to play a catalytic role in making it happen. It is the kind of program that I will be urging the Foundation, and working with the Board, to establish for NSF.

Mr. **Brown**. Can you do that within the framework of your existing funding without the special line items which you have under science and engineering education?

Dr. **Slaughter**. The process will be more protracted, certainly. But I don't think there is any reason that we can't move in that direction.

Mr. **Hays**. Mr. Brown, the Department of Education would be delighted to work with NSF in seeing how we could address the priorities you have suggested. I think that is a very, very positive statement, and we would like to see what we could do to use our authorities to assist.

Dr. **Hogness**. Mr. Brown, speaking more as a former university president than a member of the Board, I believe it is a very important proposal. As a matter of fact, it is something that we should have been doing more of before, and at one point we were doing more as universities than we are doing at the present time. I also can say that the present draft report of the Board subcommittee on science and engineering education, which has not yet even been approved by the committee does contain such a suggestion. Now, how that will be implemented through the National Science

Foundation is something we will have to work out, but it is very important.

Mr. **Brown**. Well, I make the suggestion because it represents a line of thinking which I have tried to emphasize over the past several years. That is that we have tended to abdicate responsibilities as institutions, and in so doing we have not served the country well and that we need to bring those responsibilities back into some more effective relationship. And industry has a responsibility, universities have a responsibility for the health of the system which feeds students and manpower to them. If they don't accept that responsibility, it is going to deteriorate.

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Brown.

If I may, along the same lines, there is a recognition in your testimony, Dr. Slaughter, that one of the reasons that the programs in the science education area did not compete with other priorities was that they were relatively small—submarginal, in your words. You indicated that there were a number of these small programs that were mandated by statutes, some 27 subelements that taken individually more not able to really address the size of the problem that they were designed to address. Therefore it is true that a program like that would not be able to compete with the others that might have been more effective in addressing the problem.

My question is perhaps we, from the legislative standpoint, should be pulling back from these smaller mandated programs. If there is a consensus on the committee to support science education to some degree, the question is would the National Science Foundation be able to function in these areas more effectively if we reorganized the science education program from the legislative standpoint, eliminated some of the more detailed mandated subcategory type programs and gave you greater flexibility to use perhaps a reduced number of dollars, but nonetheless use them in the area of promoting science education? That is the block grant philosophy. I hate to think that it is that, but—could I ask Dr. Slaughter and perhaps Dr. Gillespie if that would be a constructive approach from your point of view?

Dr. **Slaughter**. I believe that it would be constructive if we could emerge with a program that has greater coherence in addressing the really important issues of science and engineering education. I think we are at a point in the Board's process of looking at science and engineering education where we will be able to identify the directions that the National Science Foundation should pursue—many of them in the area of the discussion that we have just been having with Mr. Brown. Coherence in those programs would allow us to identify a more substantive level of funding necessary to do a good job. That is the kind of thing that might emerge.

Mr. **Walgren**. Is there a comment from Dr. Gillespie?

Dr. **Gillespie**. Well, I would certainly second what Dr. Slaughter said. And of course managers of programs always hope for as much flexibility as possible so that one can look at substantive issues and put together a program which could address those issues. So I have always tried to get as much flexibility as possible.

Dr. Hogness. Mr. Walgren.

Mr. Walgren. Yes.

Dr. Hogness. Could I just answer your question from the Board point of view by saying yes.

Mr. Walgren. OK.

Mr. Ertel.

Mr. Ertel. Thank you, Mr. Chairman.

After our last interchange, Dr. Slaughter, a flurry of notes came floating up here from staff, so I think I ought to follow up on those, although we are not having a hearing on the ocean margin drilling program. One note that came floating up says it is a year-by-year agreement that you have with the oil companies. It could be changed for fiscal 1982. Is that true?

Dr. Slaughter. Yes, that is true.

Mr. Ertel. Another note said that all the Government contracts carry a clause providing for termination at the convenience of the Government. So you in fact could terminate it for 1982. So, therefore, there was no suggestion that you look at the fiscal year 1982 contract with the oil companies to change either the mix, percentage, if you will, or just eliminate the Government. It seems to me if I were sitting on the National Science Foundation's Board and I was interested in science education, knew that I had a problem with funding, also knew that I had an ocean margin drilling program which the administration in the first round, at least, told me to continue, that I would go back to the oil companies. I would say, you know, you have had awfully large profit increases in the last year. This may in fact benefit the oil companies even more. Some of them had a 300-percent increase in net profits. Has anybody made the suggestion that maybe their participation ought to be a little higher?

Dr. Slaughter. No, that has not been suggested thus far, Mr. Ertel. I think that we also ought to look at this particular program from another point of view. It represents an important thrust by the Government to effect a meaningful way of bringing together Government, universities, and industry in a major scientific exploration program. We believe that it is a model worthy certainly of further evaluation; we should not in a precipitous fashion make changes that could cause a lack of interest among the oil companies in participating in the scientific program. This participation and support certainly could have been examined. We chose not to, largely because of the press of time.

Mr. Ertel. Thank you very much, Mr. Chairman.

Mr. Walgren. Let me just ask, the question it seems to me is not whether or not there will be an ocean margin drilling program, but who will pay for it. And before we become apprehensive that the participation of the oil companies might decrease, we should at least ask them. Now, I haven't noticed the administration putting much value on any other Government programs related to the oil companies and the whole philosophy is that with respect to the area of energy, the private sector is supposed to take almost all of this. And my question is: Did we at least ask the oil companies whether they would pick up the $12 million share in the ocean margin drilling program so that we could continue other areas that we know no private part of the market is going to pick up? Did we ask them?

Dr. **Slaughter**. No, and, Mr. Chairman, this is not an energy program. The ocean margin drilling program is a major scientific investigation in the most important area of geology existing in the world today. Exploration of the margins is one of the largest remaining questions facing scientists who are interested in learning more about the evolution of the Earth and about the geological history of the Earth. It is designed to answer some scientifically important questions having to do with seismicity, having to do with the evolution of much of the world in which our Nation exists. The sediments there have a history unknown at this point, they have never been sampled. Consequently, they present some key scientific questions, and the oil companies have expressed a willingness to participate in finding answers to these questions.

Mr. **Walgren**. Well, I don't mean to belabor a point either. My only suggestion from my personal viewpoint is that when you have expressed the obvious interest of a financially capable part of the private sector in an area like their present participation to the degree of one-half payment of all the costs involved in this program, wouldn't it be prudent to ask whether or not they would do more before we zero out functions which you have put great importance on and feel very badly that we are sacrificing?

Dr. **Slaughter**. Mr. Chairman, that question can be asked of the companies. We are at the moment establishing the process whereby we will begin discussing the involvement of the oil companies in fiscal year 1982. It is true that it is a negotiated set of agreements, and we are going to be involved very soon in negotiating the 1982 agreements between the oil companies. We will be discussing their level of participation.

Dr. **Langenberg**. Mr. Chairman, if one is to pursue this line of reasoning, one will find it helpful to remember the order of magnitude involved. The funding originally proposed in the January budget for the ocean margin drilling program from the NSF was $16 million. If one were to obliterate the ocean margin drilling program, that would still not resuscitate science and engineering education at any level funded within the rememberable past.

Mr. **Ertel**. Mr. Chairman, if the chairman would yield.

Mr. **Walgren**. Be happy to yield.

Mr. **Ertel**. My recollection is that that is a very sizable program over the next 10 years, somewhere in the range of $700 million.

Dr. **Langenberg**. Actually, it is about $800 million.

Mr. **Ertel**. The $800 million in the next 10 years in science education would certainly be a step in the right direction, at least in science education. And one could argue, and I think it is a judgment that this committee should make, whether or not we want to embark, if you will, on a $800 million program in this area and give up science education. I think that is a valid consideration for this committee, Mr. Chairman. If I am correct on my figure.

Dr. **Langenberg**. You are correct on your figures. But it is useful to remember that that $800 million is not Federal funding. That includes the oil company contributions out through the end of the program. It also includes research funds in the Earth and ocean sciences which are currently being expended in other areas; for example, in the deep sea drilling project. That $800 million is the total integrated cost from all sources for the program. And even that $800 million is something less than what you would have had if you simply projected forward for 10 years the science and engineering education budget at the current year's level.

Mr. **Ertel**. Well, I agree with what you say. Half of that will be the Federal Government's contribution under the agreements, 50-50. That is $400 million. But, you know, just because you are not going to have the science and education 100 percent funded doesn't say to me that you shouldn't use some money in the science education field. I don't understand that all or nothing sort of approach.

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Ertel. I want to give Mr. Gregg at least an opportunity at this point. I realize that you——

Mr. **Gregg**. No questions, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Gregg.

Well, we appreciate the presence of the panel, and apparently representatives of the NSF will be back before us on the 17th; is that correct? The 12th and the 17th. And we will be able to pursue some of these subjects at that point.

Thank you very much.

The next presentation will be made by Joan Ganz Cooney, who is the president of Children's TV Workshop. I understand the Children's TV Workshop has been the originator of such programs as Sesame Street and 3-2-1 CONTACT with some help from the Federal educational establishment. We are particularly interested in that because it is in that area that the absolute cuts proposed by the administration will have severe effect.

We are very appreciative you could come to the committee. Someone said that you had brought Big Bird with you. Is that true?

Mrs. **Cooney**. No. He had to work today on another show.

Mr. **Walgren**. Oh. Welcome to the committee, and please proceed as you see fit.

STATEMENT OF JOAN GANZ COONEY, PRESIDENT, CHILDREN'S TV WORKSHOP

Mrs. **Cooney**. Thank you, Mr. Chairman.

I have a few brief remarks to make and would like to show you some film, but I want to introduce my colleague, Dr. Keith Mielke, who directed the 3-2-1 CONTACT project for us and its very considerable research in connection with that project.

I would like to address the urgent needs of American children for science education, and the contribution that television can make in addressing those needs.

We are aware that the administration is considering elimination of all funds for science education. We hope this will not happen. America's need for science education is too great.

For most areas of government, this is not a time of expanding budgets; but it is a time of increased attention to efficiency and cost effectiveness. Television in the service of science education must be examined under the same rigorous standards as all other approaches.

In 1980, the Children's Television Workshop premiered 3-2-1 CONTACT, a science readiness series for children 8 to 12 years old, which was funded by the National Science Foundation, the Department of Education, the Corporation for Public Broadcasting, the United Technologies Corp., and CTW itself. We consider this amalgamation of business, private and Government support an ideal means of paying for this kind of national service.

Let me make clear that we have proposed funding by NSF and others of a second series of science programs, so we are very much an interested party. And CTW's interest, like NSF's, is tangible: we both have invested millions of dollars through 3-2-1 CONTACT.

We both share a common concern about our young people's knowledge and attitudes toward science and technology. By and large their knowledge is inadequate and their attitudes negative. The consequences can be serious.

We could become a third-rate industrial nation within a generation, if not sooner. I say this as much in sadness as in anger because there are those who believe the United States has already become a second-rate industrial power.

The statistics are ominous: in Japan today, for every 10,000 citizens, there are 400 engineers and scientists as compared with only 70 in the United States. Japan, with about half our population, has now surpassed the United States in the number of degrees granted to engineers.

As George F. Will has noted recently, our output seems to be much better with lawyers than with engineers. In the 1940's, engineers increased by 83 percent, and lawyers didn't increase at all. In the 1970's, the situation had virtually reversed itself: lawyers increased by 83 percent, and engineers increased by only 15 percent. Now, don't get me wrong. Some of my best friends are lawyers, and I certainly do not challenge their importance. However, our country's industrial and military power inevitably rests on science and technology. On this front, we are not doing well, particularly among our young people.

This was stated dramatically in a recent NSF report which said, "Students who take no more mathematics and science after their 10th year in school have effectively eliminated by the age of 16 the possibility of science or engineering as a career." That's why our own advisers for the 3-2-1 CONTACT series stressed the critical importance of the elementary school years in promoting science readiness. By the time children are in high school, it is often too late.

The National Assessment of Educational Progress reports science knowledge among young people is in a long-term state of decline.

More basic, however, are children's attitudes toward science in their crucial elementary years. The National Assessment finds that only 6 percent of 9-year-olds listed science as their favorite subject in school, and 27 percent had already decided that a career in science would be too much work—and these opinions are found before most children have even met their first full-time science teacher.

Many schools are under severe pressure to get "back to basics." This all too often has meant assigning a lower priority to science education. This is being done at a time when science education should get increased attention—and not just by the schools alone, but by all institutions and all media that can make a contribution. This includes the most powerful medium of all—television.

The 5 minutes of excerpts from 3-2-1 CONTACT that I have brought with me today and which I would now like to show you do not summarize the entire series of 65 programs. They are short clips from longer pieces that will suggest some of the flavor of our approach and a sense of the range of topics we cover.

[Film: 3-2-1 CONTACT excerpts.]

You can see from these excerpts some of the possibilities television provides in science education. But what of its reception and costs?

The economics of television differ from those of classroom instruction. Formal classroom education is largely a local and state affair. Production of children's television at these local levels is simply uneconomical in terms of program quality affordable and costs per viewer reached. But by building large audiences nationwide we can achieve significant economies of scale. At CTW we have proved this concept many times during the last 12 years in the production of series such as Sesame Street and The Electric Company.

Let me illustrate with the results from the first season of 3-2-1 CONTACT, which is being distributed nation-wide twice each day, and which will be aired at least four times over a 2-year period on most of the 260 local public television stations. In its initial run, 3-2-1 CONTACT reached more than 23 million home viewers, accounting for over 118 million program exposures or instances of viewing. These estimates are based on audience data from the A. C. Nielsen Co. When we divide these home viewing estimates into the cost of producing the series—including research, advisers, and audience building efforts—the cost for a single viewing comes out to about 7 cents. Even this low cost per exposure declines sharply when school audiences are taken into account, and as repeat broadcasts are viewed in both homes and schools. In short, television can be a very cost-effective educator.

And the schools have responded enthusiastically to 3-2-1 CONTACT. More than 250,000 elementary teachers requested our teacher's guide for the series, and school surveys indicate that the series is very popular in the classrooms.

Furthermore, with 3-2-1 CONTACT, we have been able to build alliances with other institutions and groups, inspiring special programs in science museums, and even new science merit badges for the Girl Scouts of America. The show's impact has thus become very widespread.

And yet, despite the cost effectiveness of this program, and its universal acceptance and the fact that millions of children are not getting adequate science training in this country, we are still faced with the sure knowledge that if NSF science education funding is eliminated, there can be no more 3-2-1 CONTACT programs produced.

In conclusion, I urge the subcommittee to:

Consider what it takes for the Nation to prosper, and ask if that is possible without a strong base of science and technology among our citizens, starting with our youth;

Look at our lagging status in science education and ask where our scientists and engineers will come from;

Look at the critical years of the elementary grades when the doors start to close on future careers in science, and ask what must be done to reverse a disquieting downward trend;

Look at television, and at all institutions and media, and ask what unique contributions each—including the Federal Government—can make;

And do look at the cost effectiveness of science education programs on television.

I am sympathetic to the administration's aim to cut the budget, but in this case we could be cutting the very heart out of America's future capacity for innovation and leadership in both the military and private industrial sectors.

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you very much. We appreciate that.

Would you like to make a statement, Dr. Mielke?

Dr. **Mielke**. No.

Mrs. **Cooney**. We would be happy to respond to any questions.

Mr. **Walgren**. Well, let me certainly express my appreciation both for the content of the programs and, as someone who is looking forward to being around small children, for what has been done in that whole area. And it is not just for children. A lot of adults spend a great deal of time looking at those programs as well. Thank you very much.

I want to turn to the other members of the panel.

Mr. Dymally, any questions?

Mr. **Dymally**. No.

Mr. **Walgren**. Mr. Shamansky?

Mr. **Shamansky**. Mrs. Cooney, I indicated to you earlier that I am actually a great fan of Sesame Street. I cannot resist singing the ABC's when it comes on. I think that is a testimony to its effectiveness, and I find this equally effective.

Have there been any studies with respect to the impact on children of the series after its initial run? In other words, is there an increase in science that we can see later on, or hasn't enough time passed?

Mrs. **Cooney**. We have not had time to do that kind of an evaluation of the series, partially because it is a very new series. It would be very hard to get that effect. Second, it is science readiness, and it would be extremely hard—and Dr. Mielke can speak more specifically on this—for social scientists to get at its effects very soon. I would remind this subcommittee that Project Head Start, of which I was and am a strong supporter, showed very little effect in the first grade, and that almost scrapped the program. And yet in the sixth grade it has been found that the Head Starters can be recognized right away. So we are not sure how to get at some of the effects of this kind of a readiness program.

Do you want to add anything to that?

Dr. **Mielke**. I would add the program is being evaluated constantly and of course exists in a rather fishbowl-like existence. It is being evaluated by school curriculum committees, evaluated by such organizations as the Girl Scouts of America which has made an unprecedented cooperative move with 3-2-1 CONTACT to incorporate it into their merit badge program. It is evaluated by the schools and teachers who request teacher's guides. It is evaluated by parents who write us unprecedented volumes of mail telling us what their children are learning from it, and by the children themselves.

Mr. **Shamansky**. With reference in your statement to 7 cents per viewing cost, how does that compare to the commercial cost of many products?

Mrs. **Cooney**. Well, I am not so sure about that.

Mr. **Shamansky**. Or is that a fair comparison?

Mrs. **Cooney**. Do you mean commercial television?

Mr. **Shamansky**. Yes. To me, 7 cents per viewing seems to be a reasonable cost for a young child watching that kind of thing. My question is how would we compare that to the commercial world selling soap or anything else? The expense of production of that?

Mrs. **Cooney**. I think that would be a little hard comparison to make.

Dr. **Mielke**. It is a little bit of apples and oranges.

Mrs. **Cooney**. I would add, this type of material is probably the most expensive in all of television to produce because you start with research. You research the children, and what is going on in science education in schools. You have advisers. And so the startup costs are quite high. And we do all through this kind of work what we call formative research. We have a group of researchers feeding back information to producers from the field on whether the children like the material and are learning from it. So I would say the initial cost of this kind of programing is high. Yet the fact that it is repeated and has a longer life makes it cost effective over time.

Mr. **Shamansky**. I am assuming it is designed to not lose its current aspect.

Mrs. **Cooney**. That's right. But in the television atmosphere that we live in today, 13 weeks of programing—and that is what we have here, 56 half hours—will wear out with children very fast if it is just repeated over and over again. "Sesame Street" makes 130 new hours every year. It uses a great deal of old material, but in new ways, so we have gotten it down to a cost-effective way of keeping it evergreen. But we do new material in that show every year. "Captain Kangaroo" is in its 26th year. This is a commercial television show for youngsters. It does new material every year. You can't just live forever with 56 half hours and expect to retain an audience in the commercial television atmosphere we live in.

Mr. **Shamansky**. Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Shamansky.

Mr. Ertel.

Mr. **Ertel**. Thank you, Mr. Chairman.

My wife was one of the first teachers in Head Start, so I appreciate your comments. She also taught in this area. My children watch "Sesame Street" and the science programs as well. So all I can say is I don't have any questions. I am supportive.

Mrs. **Cooney**. Thank you.

Mr. **Walgren**. How many hours do young people watch television?

Mrs. **Cooney**. Well, alas, it is high. And it can range—it can go up very high. The television set, I believe, is on in most homes for young children 56 hours a week. Now that doesn't mean the children are viewing, but it is on. The average viewing of young preschool children is 27, 28 hours a week. By the time a child finishes high school, he will have spent much more time in front of the television set than in the classroom. It is the most heavily used piece of equipment or furniture in America. It is used more than the bathtub, and, we are told, more than the telephone.

Mr. DYMALLY. Mrs. Cooney, that is not all good, though.

Mrs. COONEY. It is certainly not.

Mr. DYMALLY. So it is good to have this kind of scientific program.

Mrs. COONEY. Yes. I have said that if television is that used, then can we make it a more constructive thing in American life? And if it is going to be a babysitter, can we make it a responsible babysitter? This is what I originally asked of the program that became "Sesame Street." "3-2-1 CONTACT" is for older children. But there is very very little on for children 8 to 12 that is instructive or educational; almost nothing. And that is the second heaviest viewing population in the United States. The heaviest viewing is the preschooler.

Mr. WALGREN. Somebody once said that human beings will watch something rather than nothing. Right?

Mrs. COONEY. Right. That is what we have learned in this business.

Mr. WALGREN. What has been the extent of the Federal support for this particular program and then perhaps even the "Sesame Street"?

Mrs. COONEY. Well, "Sesame Street" began 50 percent funded by private foundations and 50 percent funded by the U.S. Office of Education and the Corporation for Public Broadcasting. I was never sure if that was direct Federal funding or indirect Federal funding. But it was 50 percent Federal funding. Now "Sesame Street" is pretty much self-supporting. We merchandise books, records, and playthings featuring the Muppets. Those moneys go back into keeping "Sesame Street" alive and well. Stations that purchase the show pay for it, the public stations pay a license fee. The Federal Government gave us a real chance to make that show self-supporting. Secretary Weinberger, when he was at HEW, talked about putting it into repeats. But I went to several friends in the Government and said, "give us 3 or 4 more years of funding and we won't be coming back." And so we are about finished asking for Department of Education support for that show.

Whether a show like "3-2-1 CONTACT" could ever become self-supporting, I am not sure. But I do feel that it should be continued—and we should have at least 130 half hours of it to make it more effective for children. The Federal contribution, between Department of Education and NSF, is what percentage of the total?

Dr. MIELKE. It is approximately half.

Mrs. COONEY. It is approximately half.

Again, United Technologies put in $2 million, the Corporation for Public Broadcasting put in $747,000. The "Children's Television Workshop" itself is a large contributor. NSF is the largest, and CTW is second with $2,673,000.

We are permitted by an agreement with the Office of Education to put moneys that "Sesame Street" makes into other approved projects. The Ford Foundation gave us a grant a few years ago of several million dollars which we have invested and earns money the way a small endowment does for a university. So we have what we call our own money and we do put it in educational television. So we ourselves are supporters of our own shows—partial supporters.

Mr. **Walgren**. Would the minority staff like to raise a point?

Mr. **Scoville**. Yes. Thank you, Mr. Chairman.

One thing I noted with interest was you were talking about the ability of local communities to produce their own television programs and you basically said that the cost was too high for them to undertake it on an effective basis. I agree with that point. One thing that intrigues me, though, is we are in the midst of an information revolution. The cost of producing television and the use of information is dropping drastically. Do you foresee in say 10 years a greater ability of communities to produce their own programs which might complement, say, the national efforts such as those that you are undertaking?

Mrs. **Cooney**. By all means. And that in fact is going on now. There are a number of in-school television programs that have been created locally and then purchased by other stations and used within regions. They tend not to be as highly produced or have that gloss that people have come to expect from the most highly produced shows. But there is no question we are in the midst of a revolution. If I had to make my bet, though, right now, I would say that over-the-air broadcasting is going to be how to reach the most people all at once during the next 10 years. There will be some fragmentation from cable, from satellites, and so on. But there is no question that over the air broadcasting is the most effective way for at least the next decade if you want to reach a lot of people all at once.

Mr. **Scoville**. Thank you, Mr. Chairman.

Mr. **Ertel**. If the chairman will yield for a question.

Mr. **Walgren**. I will be happy to yield.

Mr. **Ertel**. I noted the figures you gave there on the financing for "3-2-1", and I think you said $2.6 million, something like that, from Children's Workshop.

Mrs. **Cooney**. Yes.

Mr. **Ertel**. How much does NSF give?

Mrs. **Cooney**. NSF gave $3,651,000.

Mr. **Ertel**. If in fact the science education program were cut off, and in fact it cut off NSF funding for you, what would that do to your program?

Mrs. **Cooney**. We can't go forward without NSF.

Mr. **Ertel**. In other words, the practical effect of the zeroing out in the budget science education is to zero out the program you presented here?

Mrs. **Cooney**. That is correct. I would add that the Corporation for Public Broadcasting is a funder and that they too are having problems now. The Department of Education was a funder of the original series, granting us $2,200,000. However they are going to have funding problems also. But I would say the NSF cut would kill "3-2-1 CONTACT" if we can't have NSF funds as lead money.

Mr. ERTEL. So that brings up very graphically the question of whether we want an ocean drilling program as compared to science education. And you have given us a pretty good example. Thank you.

Mr. WALGREN. Thank you, Mr. Ertel.

I want to recognize the presence of the ranking minority member of the full Committee on Science and Technology, Mr. Winn. We are pleased you are with us.

Mr. WINN. Thank you, Mr. Chairman.

Mr. WALGREN. Thank you very much. We really appreciate your having come.

Mrs. COONEY. Thank you, Mr. Chairman.

Mr. WALGREN. The next panel is made up of Dr. James Rutherford, who is a former Assistant Director for Science Education of the National Science Foundation. He is a former member of the faculty of Harvard University, who has been involved in a number of scientific issues for a long time.

Joining Dr. Rutherford will be Dr. Lilli Hornig. Dr. Hornig is from—particularly of interest to this committee is her origin in Congresswoman Heckler's district. She is with the Higher Education Resource Service of Wellesley College, an organization concerned with the education and employment of women in science. Dr. Hornig is a chemist by training and has been chair~~woman~~ of the Department of Chemistry at Trinity College. We are pleased you are here.

Let me ask Dr. Rutherford to proceed first and then Dr. Hornig.

[A biographical sketch of Dr. Rutherford follows:]

DR. F. JAMES RUTHERFORD

F. James Rutherford, currently advisor to the American Association for the Advancement of Science, served as Assistant Director of Science Education of the National Science Foundation before becoming the first Assistant Secretary for Research and Improvement in the newly created Department of Education. Prior to his Federal appointments, Dr. Rutherford was on the faculty of Harvard University as associate professor and Director of Harvard Project Physics, and then at New York University, where he was professor and head of the Department of Science Education and Director of Project City Science. Dr. Rutherford has also taught high school science and written extensively on issues in science education.

STATEMENT OF DR. JAMES RUTHERFORD, SCIENCE EDUCATION OFFICE, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Dr. RUTHERFORD. Thank you, Mr. Chairman.

It is a pleasure to be invited here, all the more so since unlike former years, I represent no known organization. I have been a high school teacher and a university professor, but I am not here representing either precollege education or higher education. They can take care of themselves. I have been active in scientific and science teaching societies, but it is not my job to speak for them. I have been an official in the previous administration in both of the agencies that are represented here today, but clearly I did not come here to speak for the previous administration. Nor, for that matter, to support or defend the current one.

I do, therefore, represent myself, but I also think that I am here on behalf of all those people who are concerned about the health of this country and our ability to get on with the job of reaching the sort of democratic, free, open society that we must have. In order to do that, we must have the kind of national security that protects us from external threats, and the kind of productive economy that allows us to turn ourselves to our social and cultural agendas. And I speak to you at a time of crisis, a crisis that is already here.

George Orwell would have been amazed to hear today the kind of testimony we have had to receive from these two agencies. Here we are, after the National Science Foundation and the Department of Education did an 8-month-long study to examine the conditions of our country and reported back to us that on every front the system is weakening: Test scores are going down on the average in any and every test we have, the scores of the very best students are going down, the number of qualified science and mathematics teachers is decreasing, and the university system is not generating many new ones, everywhere you look there are students taking less and less science. The industrialists and the business people and the military claim that they cannot find people who have the technical qualifications to adjust to the modern systems.

In the face of that very report, we are told today by NSF that we must take this radical step of zeroing out science education, which is referred to somehow as a "balance between research and education." I don't know how you balance a billion against zero. And the Education Department for its part has nothing to say about how it intends to address this national crisis, this national weakening of science education, which surely affects our economy and our security.

In the outline that I have given to you, Mr. Chairman, which I will not go through, I have presented the argument that: First, the Nation's security and economy depend upon technological innovation; second, technological innovation requires a strong R. & D. enterprise; and third, you cannot in fact do good research and development unless you have enough outstanding scientists and engineers.

I would like to say, however, that while most of the discussion in this session and in the papers has been with regard to the generation of scientists and engineers, in fact the technological and scientific strengths of this Nation and its wisdom in putting innovation to work, depends not just upon scientists and engineers. It also depends upon businessmen and legislators and other leaders who make the daily decisions about how we use our resources and whether we invest in more science or not. And it depends upon the quality of the work force.

The decision in the Soviet Union to upgrade the mathematics and science education of all students, which is a dramatic thing, was based on the conclusion that it was simply not enough to train an elite, as they had done for over 25 years, but that the military system and their factory system demand people who are highly trained in science and mathematics.

So what I would prefer to do, rather than repeat that argument in detail, or recite all the things that seem to be going wrong in the educational system is to talk about the Federal role in science education. There is a lot of popular talk around in the form of slogans, mostly empty ones, I believe, that education is altogether a State and local responsibility and, therefore, the Federal Government has nothing to say or do about it. That, of course, flies in the face of our total educational history. Almost every major change in the educational scene in America has been brought about by some Federal action. I refer you to the Land Grant College Act of 1862, which linked agriculture and science and education and resulted in the strongest agricultural system in the world.

I remind you that in 1944, the GI Bill of Rights was a Federal initiative, the purpose of which was to address the shortage of educated professionals that we needed for our resurgent peacetime economy. That GI bill worked, and it demonstrated that the Federal role is a significant and important one that achieves purposes that go beyond resources.

I remind you that, in 1950, the National Science Foundation was established to strengthen scientific research potential and science education programs at all levels; not just graduate education, not just postdoctoral, but at all levels. It was a wise move, and it resulted, in the 1960's, in strengthening our scientific education and the building of the strongest scientific and engineering country in the world. Now we are being told that we are going to abandon that effort.

Mr. **Dymally**. What year was Sputnik?

Dr. **Rutherford**. Sputnik was—somebody help me—1957?

[Chorus of 1957.]

Mr. **Dymally**. So NSF preceded the Sputnik.

Dr. **Rutherford**. It preceded it. It had the authority——

Mr. **Ertel**. Let the record show we had everybody respond to that question.

Dr. **Rutherford**. Yes.

I would like to point out that there have been seven Presidents and 15 Congresses that have supported the notion that the National Science Foundation needs to be involved in science and science education. In spite of the testimony that you heard today, this is the most radical revision in scientific policy that has happened since the beginning of the National Science Foundation itself. Do not believe that it is merely a matter of budgets up or down a little bit. It is a question of whether or not the Federal Government intends to pay any attention to the national crisis in science education.

Now, what to do about this. Well, perhaps we all have our solutions. Let me suggest just a couple of things and indicate that we ought to be hearing from the Department of Education and the National Science Foundation on what they intend to do. First of all, we need some sort of a strategy. The question was asked very well today. Does this administration have a strategy to deal with our deteriorating science education establishment? The answer is no, it does not. The former administration just barely had a policy, was just beginning to have one. I would certainly not, even as a member of that administration, hold it up as what it ought to be in the face of the national scene. So that is the first job. But don't believe that the NSF will generate a strategy when they get rid of science education directorate and there is nobody there to do it. That is not the way agencies work.

Second, we have to have support for the Foundation that is flexible, so that whatever the budget is, it can be put to the most appropriate uses. But just remember that if flexibility is provided, one still has to think of science education as a total system that begins with young children, goes through those crucial early adolescent years, through the secondary school and the colleges and the graduate school. And you can't treat the system at any one point. I argued before this Committee on previous occasions on the importance of the early adolescent child to the future of our scientific enterprise, and I am proud to say that the 3-2-1 CONTACT series was started during my tenure, and it has had good effects. So there should be flexibility in the system, but it should be demanded that the response of NSF goes across the spectrum and focuses on crucial areas such as the adolescent child.

I think the NSF and the Department of Education should help upgrade the subject matter competence of science teachers. Now, one might argue that that can be done locally. Mr. Chairman, science teachers in this country have only had advanced training in their fields on those occasions when the Federal Government saw that it needed to help out. The system is not built and funded in a way that allows it to happen otherwise.

We learned how to do it in the 1960's. We had much better science teachers. Now we are losing the teachers and they are not being retrained.

Another thing that can be done easily and needs to be done because it can't be done without Federal leadership, is to accelerate the introduction of new technologies into our schools. That can come from the Federal enterprise. It is done for industry; it could be done for the schools. We need to join with the States and communities in modernizing science teaching instrumentation, especially in our engineering schools. It is incredible at the same time we are talking about the failure to have up-to-date engineers to make our industry work, we are being told that we should not help universities and engineering colleges in this regard.

Finally, it is up to the Federal Government, in my judgment, and the NSF in particular, and the Department of Education to some degree, to help those community agencies such as museums, and the media, such as 3-2-1 CONTACT, and others to bring the message to all the people who are outside of the schools and colleges and who need to understand what the stakes are.

I should also add that in spite of all this talk about science for industrialization that the Government, Federal Government, provides essentially all of the funding for basic science, that is to say, that kind of science which helps us understand the natural world. The taxpayers are paying for that research, and therefore they deserve to understand the fruits of scientific research, whether or not they are going to become scientists. And to bring that to happen, there has to be input from the National Science Foundation.

It is true that budgets are usually developed by way of a long, drawn-out process. That process convinced the National Science Foundation that it should ask for over $100 million. Inside of weeks, without process, we heard that it should be zero. I think that should be understood for what it is, a total retreat on the part of the Foundation from involvement in science education! It will not be put back in, because it is always harder to put things back in. And if you look at the Department of Education budget carefully, you will see that what they have been talking about in the way of cooperation is past history and that they, in fact, are not investing in upgrading the scientific and technological education of our Nation.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Rutherford follows:]

Outline of testimony given by F. James Rutherford

Before the U.S. House of Representatives

Sub-Committee on Science, Research & Technology

On March 10, 1981

The Crisis in Science Education

1. The science education crisis (meaning the serious nationwide decline in science, mathematics and engineering education) is best seen in relation to what are generally perceived to be the Nation's two dominant needs:

- To strengthen our military capability. In order to be able to pursue the improvement of the quality of life for all citizens, it is necessary first to ensure that we are safe from external threats to our survival as a democratic society.

- To revitalize our economy. The poor performance of the national economy hurts almost everyone (some by loss of jobs, some by business failures, all by inflation), and undermines our ability to deal effectively, if at all, with other urgent problems in our society.

2. Addressing these needs effectively will involve many actions and policies in all sectors, but in both cases technological innovation is essential.

- Military power is not static but something that must be improved constantly. This comes about not so much by increasing "fire-power" as by increasing the use of sophisticated technological devices and systems (microelectronics, sensors, cryptogrophics, computer networks, etc.). The U.S. can stay militarily ahead only by developing and utilizing ever more complex technologies--just buying more of today's weapons won't work in the long run.

- Undoubtedly it is our lagging industrial productivity that is crippling the economy. Other countries are achieving greater productivity than the U.S. through more agressive employment of new technologies.

3. But successful technological innovation just doesn't happen in response to "market forces" or to wishful thinking. How effective we can be at technological innovation depends on how good we are at:

- o Generating new technologies through scientific R&D
- o Utilizing the new technologies in business and industry.

4. Scientific education (i.e., in science, math and engineering) must be of the highest order if the U.S. is to remain a world leader in scientific R&D and if it is to become more adroit in the utilization of technology.

- o High quality R&D depends on having outstanding scientists and engineers to do it. The process of identifying and training of talented young people to become scientists and engineers is a long one that cannot be turned on or off or dealt with by paying attention to parts of the system only.
- o Business decisions and government policies (local, state and federal) influence, if not determine, just how much and what kind of innovations will be implemented, and how much will be invested in R&D. The education in science of those non-scientists who make such decisions and set those policies therefore becomes exceedingly important.
- o The productivity ~~and~~ efficiency of most workers--in the office, at the factory, in the armed services--is coming to depend on their willingness and ability to use new scientific technologies. Thus the education in science and math (and language) of the citizens who form our workforce assumes more importance than ever before.

5. But every sign indicates that our position in science education, absolute and relative, is weakening rather than growing stronger.

- o Our economic and military competitors are increasing the amount of science and math studied by all elementary secondary students, and up-grading the quality, even though their requirements were already higher than ours.
- o By contrast we are demanding less and less science and math of our students, providing fewer and poorer quality teaching resources than 10-15 years ago, relying more and more on unqualified science and math teachers in our secondary schools, and we are not investing (at any level) in up-grading the system. Some indications of our decline is shown by the steady decline of the average scores on national tests of many kinds, the alarmingly small amount of science studied by most American high school and college students, and the increasing difficulty that business, industry and the military have in recruiting workers able to learn quickly to use new technological systems and equipment to full advantage.

The Federal Role in Addressing the Crisis in Science Education

1. Since the decline in the quality and quantity of science education in the U.S. is not localized, and because the effects of that decline are national in scope, it follows that the federal government has some part to play in finding solutions. Slogans, platitudes and truisms about "state primacy" in education do not mean that only the states can be involved.

- o The crisis was acknowledged on February 16, 1981, by Secretary T. H. Bell in his address to the American Association of School Administrators entitled, "More Discipline in the Learning Process: a High Priority for the Schools of America." His call for more emphasis on science, mathematics, and modern foreign language was clear and unequivocal, and he asked, "How can we gain the momentum we lost?" Unfortunately, his answer seemed to be to exhort the superintendents and principals to give up their "obsession" with equal opportunity and to reform themselves into "a renewed and vigorous and a disciplined education establishment" in order to launch "a renewed quest for excellence." Excellent goals. However, except for the Secretary of Education being "a friendly and constructive critic--a Socratic gadfly are the back of American education," Mr. Bell had no positive suggestions of how the federal government might help harried schools and colleges achieve better education in those disciplines.

2. History shows that time and again it has been federal leadership and action that has caused education to address national needs. Examples:

- o In 1862 Congress passed The Land Grant College Act that established the link between farming, education and science. American agriculture, as a consequence, became and has remained the most scientific, technological and productive in the world.

- o In 1944 the GI Bill was passed by Congress to deal with the war-induced shortage of educated professionals to operate a resurgent peacetime economy. The Act established in the process, legitimacy of federal support for college students (for the good of the nation) and demonstrated that a larger fraction of the population could respond to advanced studies than had been thought possible prior to that time. College and technical education was never again to be considered a privilege to be reserved for an intellectual elite or a special economic class.

- In 1950 the National Science Foundation was established "to strengthen scientific research potential and science education programs at all levels..." when the national crisis in science education was publicly recognized (it had, of course, had been developing for some time, but it took Sputnick to expose it), the NSF had the authority and backing of Congress to invest federal resources and leadership. The result was the best-trained science and math teachers in the history of public education in the U.S., a revamped and up-to-date curriculum, and the invention of a university-school cooperative enterprise that became the model for every democratic nation. We are now coasting on the results, but dangerously failing to replenish the system.

3. The important question, then, is not whether there should be a federal role in dealing with strengthening the nation's science education. It is, rather, what should the role be? Some suggestions:

- Support of R&D in the learning and teaching of math and science. Supporting research is a traditional role of federal government, and one that it knows how to do well. Most states and local schools lack the resources, experience, and connections to the scientific community that are necessary.

- Help to up-grade the subject matter competence of science and math teachers, especially those in junior high schools, high schools, and undergraduate colleges. This is a function that states rarely fill and that the NSF has successfully carried out.

- Accelerate the introduction of modern technologies into schools and colleges. This involves R&D, teacher training, and also some capital investment in instructional technology.

- Join with the states, colleges and universities, and industry in modernizing the science teaching instrumentation in schools and colleges. This is especially important for engineering schools.

- Help community agencies, such as science museums, and the media, including especially television programs such as 3-2-1 Contact, that are important in motivating young people to consider scientific and technical careers.

Conclusion

If achieving national security and world leadership in economic productivity constitute our major long-term goals, then it follows that we need a strong science education enterprise. The evidence indicates, however, that in fact we lag behind all of our military and economic competitors. To rebuild the quality of science, mathematics and engineering education, much needs to be done at all levels of government, and by both public and private institutions. Among these there are activities uniquely suited to the federal government. Most fall under the aegis of the NSF, given its mission, experience and place in the world of science and engineering.

Mr. **Ertel**. Thank you very much, Dr. Rutherford. I appreciate your comprehensive and outstanding statement. I certainly appreciate it. And I see in the audience some of the people who testified for the National Science Foundation on the budget-cutting process. I hope they also heard your statement. We will be back to you.

Dr. **Rutherford**. Can I make one remark about that.

Mr. **Ertel**. Certainly.

Dr. **Rutherford**. The people you mention in the audience are my former colleagues and good friends, and I think they are victims.

Mr. **Ertel**. I would probably agree with that. But maybe they can be a little bit more advocate in the future.

Dr. Hornig, if you have a statement, we would be happy to have it, and if you have a written statement we will incorporate it in the record and you may summarize it as you see fit.

STATEMENT OF DR. LILLI HORNIG, HIGHER EDUCATION RESOURCE SERVICES, WELLESLEY COLLEGE

Dr. **Hornig**. Thank you, Mr. Chairman, members of the committee. I would like to express my gratitude for the opportunity to comment here today on the National Science Foundation's program for women in science and on the urgent need for the Federal Government to sustain and strengthen its very small commitment in this area. I am speaking not for any one, but I do speak in part in my role as chairperson of the National Academy of Sciences' Committee on the Education and Employment of Women in Science and Engineering and also as a member of the Academy's Commission on Human Resources.

I would like to talk, therefore, about the problems of women in science only very briefly. I would like to give you some figures on their place in science that I hope will surprise you. I want to do that in the somewhat broader setting of what other witnesses have alluded to, and that is the very wide public concern about the competitive position of the United States in the many spheres which depend entirely on the quality and strength of our scientific and technological capability. Among those, of course, are our economy, national security, national health, and the ability to make rational decisions about environmental and natural resource problems.

Quite clearly that scientific and technological strength and capability depends in turn almost entirely on the quality of the engineers and scientists who staff our laboratories and our industries, and of course on the quality of the teachers who must train the new recruits that you have heard are currently in short supply, and that is indeed true.

A very substantial part of our available talent for this national effort has not yet been brought into the mainstream, although there have been very marked changes in the last decade. Women now make up about 43 percent of our total labor force but less than 15 percent of the science and engineering work force. That is a waste of human talent and human potential that I think we cannot afford, and it is quite clear that the countries about whose competition we are worried, specifically the Soviet Union, are doing very much better.

Just 3 months ago, in December 1980, the Science and Technology Equal Opportunity Act was passed by both Houses of Congress as an eloquent expression of the fact that a relatively small investment in education can make available to the Nation the energies of thousands of people that have not yet been tapped.

The committee which I chair on Women in Science and Engineering has made extensive studies of women's participation in these fields, and I am happy to furnish two of our reports to the committee as part of this testimony. All of these studies have confirmed that there has been quite remarkable growth in the last decade in the numbers of women completing both undergraduate and advanced science and engineering education and then taking their places in the ranks of working scientists. The numbers of women engineers, for example, who graduate annually have increased about ninefold in less than a decade and women are currently one-fifth of all engineering students. They are now over one-quarter of computer scientists, and that proportion too has doubled in about 9 years. Even so, we have serious shortages of engineering graduates already in some fields, and there are not enough computer scientists to fill either current or anticipated needs, as we have heard in greater detail.

In both of those fields, perhaps most seriously there are shortages of college faculty and the facilities to train further students because of competition from higher salaried industrial positions. Our needs for reindustrialization, for new discoveries and for the ability to exploit them all depend on the availability not only of a highly trained and able corps of specialists, but also on the existence of a well-informed public capable of making the difficult and sometimes technical decisions involved. If we lack the foresight now to make the necessary investment in science and education, we will pay the price of further declines in productivity and in competitive posture in the next decade.

Women have become a quite indispensable part of that science and engineering work force, the more so as the numbers of newly trained men in these fields have been declining for the last 10 years. Had it not been for women's increasing participation, the shortages of engineers and computer scientists, and personnel in Earth sciences and some other physical sciences, would now be far graver than indeed they are. These increases have been particularly important in industry where the hiring rates for new women doctorates have doubled in 4 years during the mid-1970's.

I would like to stress that the women scientists that have been produced are in every respect as good as the men. That is true by all the common measures one can apply. They are not dropouts from advanced training. Women engineers in fact are four times as likely as men to complete doctorates, which is a surprise even to us. Money invested in their education is not wasted. Once employment opportunities were equalized by law if not always in fact, women became about as likely as men to pursue careers and not to drop out of the work force.

The most important factor is that women are now about 20 percent of the newly trained scientists. Those are the ones to whom we look for the important breakthroughs. But it is also essential to stress that women's ability to make noteworthy contributions hinges on the continued and sustained provision of equal opportunity in employment.

Now, despite the gains that have been made, there is still abundant evidence that our educational process is not entirely sex-blind and that the opportunities that exist for young girls in junior high and high school particularly are not quite the same as male students in entering into mathematics, science, and engineering fields. That is particularly critical because it happens just at the period when young people do indeed make their decision to become scientists. Young women who do opt for science face further barriers in college and university education.

It is interesting, for example, that in a period when 53 percent of all undergraduates are women, the women are less than 42 percent of those in the 25 leading institutions that produce science and engineering graduates. The very modest NSF programs for women—and I stress modest; the one existing program has been funded at about a million-dollar level for the last 5 or 6 years, or approximately one-tenth of 1 percent of the total NSF budget have been directed at overcoming precisely the barriers that we find and not at providing favored treatment to a special group. They have sponsored science career orientation and facilitation projects for thousands of young women. Such programs can be credited with making a contribution to their development as future scientists that returns the very small additional investment in their education many times over. The interesting thing about these programs is that they have produced many spinoffs. Private, corporate, and State contributions have all supported additional programs for women in science.

A noteworthy effort of that sort is called the Bay Area Math and Science Network in California. Its programs have involved and continue to involve literally hundreds of high school teachers and thousands of students and stimulated these young girls to seek further science education. Many colleges and universities have obtained either new or additional support from non-Federal sources to conduct similar programs.

Just last week I took part in a program like that at Columbia that was supported by several large industrial corporations and attracted about 150 very enthusiastic participants. I believe that widespread interest of this sort would not be generated without the leadership role that NSF programs played in the past.

The two recently announced programs for women scientists which look likely to be eliminated before they are altogether born had a somewhat different purpose. One program provides 3-year career research development awards to enable outstanding young women scientists to establish careers in research even at a time when faculty positions that normally provide those possibilities are simply not available. The important aspect of those awards from a public policy perspective is that they make it possible for these scientists in whose education we have already invested to contribute materially to the advancement of their fields.

The second program, a visiting professor program for established women scientists has a different purpose, allowing such women to serve as mentors and role models for women science students. Now, that is an extremely important function which is performed very routinely for male students by the fact that faculties are very predominantly male, particularly so in science fields. Women students do not have that kind of relationship with faculty, that kind of model, the introduction to the profession that they hope to follow. This program aims to provide that sort of possibility.

I would like to emphasize that because of the nature of science and engineering education, the kind of stop and go funding that is implied by the proposed budget cuts in science education is particularly detrimental. It takes many years to train a fully-qualified professional scientist, and education programs within institutions must be planned over a long sequence of years. Conversely, before science students enter on such a long program they need to have some reasonable assurance that there will be a stable and sustainable program ahead which they will be able to pursue.

I realize the realistic limitation of the budget that we are facing. I would like to suggest to you that judicious and continued modest support of science education for women gives us the opportunity quite literally to expand the pool of scientists by as much as 75 percent without loss in quality or to upgrade the quality of that pool quite substantially without increasing the number simply by broadening the base from which it is recruited or, of course, to take any of the options in between. I believe very strongly that cutting these highly effective programs now would be an abdication of our responsibility to the future.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Hornig follows:]

Science Education Programs for Women

Testimony Submitted to the
Subcommittee on Science, Research, & Technology
of the Committee on Science & Technology
United States House of Representatives

by

Lilli S. Hornig
Executive Director
Higher Education Resource Services
Wellesley College
Wellesley, Massachusetts
March 10, 1981

Mr. Chairman, Members of the Subcommittee, Ladies and Gentlemen:

I would like to thank the Subcommittee on Science, Research and Technology for this opportunity to comment on the National Science Foundation's programs for women in science and on the urgent need for the Federal government to sustain and strengthen its very small commitment in this area. I have spent many years working on these issues, as a chemistry professor and department chair at Trinity College and more recently as Director of Higher Education Resource Services and as Chairperson of the Committee on the Education and Employment of Women in Science and Engineering of the National Academy of Sciences. As a member also of the Academy's Commission on Human Resources, I have further devoted much time to the more general issues and needs of science education in the United States. My remarks today are addressed to the place of women in the broader spectrum of science and technology education and to the ways in which small support programs in NSF have contributed and can contribute substantially to alleviating shortages of high quality scientists and engineers.

This is a time of wide public concern about the competitive position of the United States in many spheres which depend on the quality and strength of our scientific and technological capability - our economy, our national security, the health of our people and our ability to cope rationally with environmental and natural resource problems. It is obvious that our scientific and technological strength and success depend in large measure on the quality of the engineers and scientists who staff our industries and research laboratories, and on the quality of the teachers who must train the new recruits that are currently in short supply.

Lilli S. Hornig

A substantial part of our available talent for this national effort has not yet been brought into the mainstream. Although women now make up about 43% of our total labor force, they are still only about 15% of the science and engineering work force. Especially in view of the demonstrated very high quality of women scientists, that is a waste of human talent that we cannot afford. In December 1980, the Science and Technology Equal Opportunity Act was passed by both houses of Congress as an eloquent expression of the fact that a relatively very small investment in education can make available to the nation the energies of thousands of capable people. Implementation of the provisions of this foresighted Act is necessary to enable both minority youth and women to participate fully in science and engineering education and to make lasting contributions to research and development.

The National Academy of Sciences' Committee on the Education and Employment of Women in Science and Engineering has made extensive studies of women's participation in these fields. I am happy to furnish two of its reports, one dealing with education and academic employment and the other with employment in industry and government, to the Subcommittee as part of this testimony. All of these studies have confirmed that there has been remarkable growth in the last decade in the numbers of women completing advanced science and engineering education (see, for example, Fig. 1 and Table 1) and taking their places in the ranks of working scientists. The numbers of women engineers graduating annually have increased about 9-fold in less than a decade and women are currently one-fifth of all engineering students. They are now over one-quarter of computer scientists, a proportion that has doubled in nine years. Even so, as you are no doubt aware, we have serious shortages of engineering graduates now in some fields, and there are not enough computer scientists to fill either current or anticipated needs. Most seriously, in both these fields there are shortages of college faculty to train further students because of competition from the higher-salaried industrial positions. Our needs for reindustrialization, modernization of obsolescent industries and methods, new discoveries and the ability to exploit them, all depend on the availability not only of a highly trained and able corps of specialists but also on the existence of a well-informed public capable of making the difficult decisions involved. If we lack the foresight now to make the necessary investment in science education, we will pay the price of further declines in productivity and competitive posture in the near future.

Just in the last decade, women scientists and engineers have become an indispensable part of that important work force, the more so as numbers of newly trained men in these fields have been declining. Had it not been for women's increasing participation, the shortages of engineers, computer scientists, and certain other specialists would now be far graver than they are. It should be noted that the increases in women scientists and engineers have been especially important for industry, where employment rates of new women doctorates nearly doubled in four years.

Since there are still many common misconceptions about women scientists, it is important to stress several facts about them. First, they are just as good as male scientists by every measure one can apply; they are high-ability students who complete their degrees as rapidly as men, in the same excellent departments; second, they are not drop-outs - in fact, women engineers are about four times more likely than men to complete Ph.D.s; third, money invested in their education is not wasted; once employment opportunities were equalized by law (if not altogether in fact) women became about as likely as men to take and hold appropriate positions rather than drop out of the work force; fourth, women are now about 20% of the newly trained scientists - the ones to whom we look for the important breakthroughs that reshape the boundaries of knowledge. It is also important to stress, however, that women's ability to make important contributions hinges on the continued and sustained provision of equal opportunity in employment. All of our findings support the conclusion that women scientists' participation in education and work depend on the availability of fair opportunity to the same extent as men's.

Despite the gains that have been made, there is abundant evidence that many women are still systematically turned away from mathematics, science, and engineering in high school and college. This is especially critical when we consider that young people usually make their decision to follow a scientific or engineering career early in high school or even sooner Even when young women do develop a taste for these fields they still face barriers in college and university education. For example, although women are a clear majority of all college students, they are less than 42% of those in the 25 leading institutions that produce science and engineering graduates. Conversely, women are still more likely than men to attend smaller, less expensive colleges that often offer no real professional education in science and engineering.

The very modest NSF programs for women in science - funded annually at about $1 million, or about 0.1% of NSF's total budget - have been directed at overcoming such barriers, not at providing favored treatment to a special group. These programs have sponsored science career orientation and facilitation projects for thousands of young women and can be credited with making a contribution to their development as future scientists that returns the small additional investment in their education many times over. The effectiveness of these modest initiatives is also evident in the many spin-offs they have already generated. Private, corporate, and state contributions have all supported additional programs for women in science. A noteworthy effort of this sort is the Bay Area Math and Science Network in California. Its programs have involved and continue to reach hundreds of high school teachers and thousands of women students, sparking their interest in science and causing them to seek further education. Many colleges and universities have obtained new or additional support from non-federal sources to conduct similar programs. Just last week I took part in such a project at Columbia University which was supported by several corporate contributions and attracted about 150 enthusiastic participants. I believe that such widespread interest will only be sustained if NSF can continue to lead the effort.

The two new programs recently announced by NSF for women scientists have a somewhat different purpose. The 3-year research career development awards will enable outstanding young women scientists to establish careers in research even if faculty positions, which normally provide such possibilities, are not currently available. The important aspect of these awards from a public-policy perspective is that they will make it possible for these young scientists to contribute materially to the advancement of their fields. The visiting professor program for established women scientists, on the other hand, will allow such women to serve the very important function of role models and mentors for women science students. Many leading universities do not yet have sufficient numbers of women on their permanent faculties so that women students can get appropriate advice and counseling, especially in the most quantitative or technical fields. These mentoring and role modeling functions are essential to the training of all students; overwhelmingly male science faculties have always fulfilled them for male students. The new program for women is merely a start toward redressing the balance.

Science and engineering education is necessarily sequential and it takes many years to train a fully qualified professional. It is therefore necessary that Federal efforts to upgrade and support science education be stable and sustained. The last decade has seen steady erosion in our support of science education, resulting in what many view as a steep decline in quality of science and mathematics teaching in our schools and now also in insufficient numbers of trained engineers and scientists. Stop-and-go methods of support for science education cannot create either the base of well-educated specialists we need to remain competitive, or the larger numbers of people who understand scientific issues well enough to make crucial public decisions. Science teachers in schools and colleges must be able to plan their programs in advance, sometimes several years; students who embark on a demanding course of study must be able to rely on stable, long-range programs. This is especially important for women students who may still feel insecure in male-dominated fields and whose participation in them is strongly dependent on the expectation of fair opportunity to pursue their chosen profession.

This is a time when we must both assess wisely our future needs for personnel in science and technology and deal realistically with budgetary limitations. By judicious, modest support of science education for women, we have the opportunity either to expand the pool of potential scientists by as much as 75% with absolutely no loss in quality, or to upgrade the quality of the scientific workforce substantially by broadening the base from which it is recruited, without increasing its size. I believe that cutting these modest but highly effective programs now would be an abdication of our responsibility to the future.

Fig. 1

Recent Trends in Proportions
of Women Ph.D.s in the Sciences

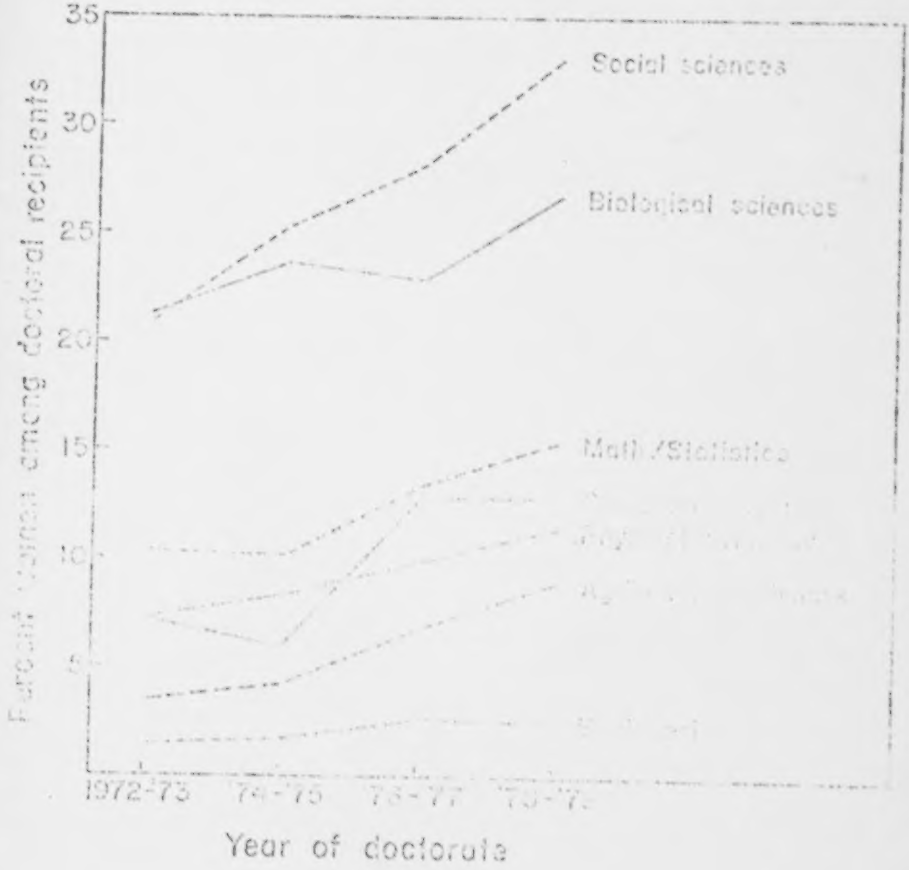

Table 1.

Recent Trends in the Percent of Women Among Bachelor's Degree Recipients in Science and Engineering

	1971-72	1973-74	1975-76	1977-78	1978-79
Mathematics/statistics	39.1	41.0	40.7	41.6	41.3
Computer sciences	13.6	16.4	19.8	23.9	25.8
Physical sciences	15.1	16.6	19.2	20.1	21.5
Physics[+]	6.9	8.5	10.9	10.5	
Chemistry[+]	19.4	20.0	22.4	22.8	
Engineering	1.0	1.6	3.2	4.5	6.7
Agriculture	5.5	9.7	18.3	22.2	24.6
Biological sciences	29.6	31.5	34.8	36.4	38.7
Social sciences	38.5	40.2	42.6	44.4	44.8

Source: Degrees Awarded to Women: An Update, National Center for Education Statistics.

[+] Percent statistics were derived from Tables 112-113, Digest of Education Statistics 1979, National Center for Education Statistics.

Mr. **Walgren**. Thank you very much, Dr. Hornig.

Mr. Ertel?

Mr. **Ertel**. Thank you, Mr. Chairman.

Dr. Rutherford, I sincerely meant what I said when I said I thought you gave an excellent statement. I am not quite sure when your role with the National Science Foundation terminated. When did it terminate?

Dr. **Rutherford**. The Department of Education started about May, and I left the Foundation just about a month before that to get started, so it was in the spring.

Mr. **Ertel**. Did you have anything to do with putting together the Carter proposed budget for science education within the National Science Foundation?

Dr. **Rutherford**. Not directly for the 1982 budget. I did for the 1981. But once again, the budget process really is a continuous one that goes back many months, and the roots of the 1982 budget were established, I would say, over 2 years ago when we changed the focus in science education there. And we set in motion a process the natural outcome of which would be the kind of 1982 budget that was submitted by President Carter.

Mr. **Ertel**. Based upon your statement, do you believe it is possible to have a viable science education program within NSF if we, in fact, zero that group within the National Science Foundation in the fiscal 1982 budget?

Dr. **Rutherford**. No. I think the claim that the investment in research also supports science education is very misleading and not the case. It supports some postdoctoral education and some graduate education. I think there has to be a focus and a responsibility, and it has to be for science education. NSF has to be charged with looking at the entire array of science education problems, including the problem of access of minorities and women, and of how you start with youngsters and go up the scale. It will not happen without budget, without a center, without people.

Mr. **Ertel**. I take it from your statement, then, that if, in fact, we zeroed the science education area in NSF for 1982, that in fact we would lose any focus on science education within that organization. Let's assume for a moment that this is a temporary aberration in American society if we were to zero that out. How long would it take us to recover and get back into any kind of role of providing for science education if we were to bring in modestly—by modestly I mean very little money in fiscal 1983 and 1984. Would we, in fact, destroy the entire science education program of the National Science Foundation for a long period of time?

Dr. **Rutherford**. I think we would. I think two things would happen, Mr. Ertel. Once something is zeroed out, it is the nature of the way governments work that it doesn't get put back in. But even assuming that something could come back in a little bit at a time, you would clearly only be dealing with bits and pieces of a very complex system. Given the preferences that the National Science Foundation has shown in the recent decade or so, I would say that the new entry would be at the technical end. That is, the training of graduate students. We would only slowly work our way down. Children who are 10 years old today in a decade are going to be 20 and will be on their way or not. So I think that the real decision is whether or not the National Science Foundation is to follow its charter or if, as the new documents indicate, they are to concentrate on the funding of basic research.

Mr. **Ertel.** Were you here, Dr. Rutherford, when I questioned Dr. Slaughter about the change in purpose as I saw the change in the document?

Dr. **Rutherford.** Yes, sir.

Mr. **Ertel.** Do you really believe there was a reorientation of policy as a result of the difference in those two documents in January and March? Did that appear to you to be a reorientation?

Dr. **Rutherford.** I am not sure how the language got there, and I had been in Government long enough to know that all sorts of things happen in the writing of documents. And I am perfectly willing to believe Dr. Slaughter's point that either of those languages is general enough to cover the waterfront. I think one looks longer than that. There has been a long deterioration in the support of science education at the National Science Foundation. This very committee has worked hard and, in fact, without this committee, the chances are that long ago there would have been a sliding off. Part of the reason that it is difficult for the Foundation to fight back against a person in OMB who apparently has no science advice is that the Foundation itself is in an ambiguous position—has been. So what this looks like to me is the final shock. In my last meeting with the National Science Board I recommended that the Board really take an honest look and decide whether or not it was content to drift along at a level of $60–$70 million, science education becoming a smaller and smaller fraction of the NSF enterprise; or whether it wanted to get out of the science education business; or whether it really wanted to get into it, even if getting into it would inevitably mean some tradeoff against research budgets in the short run. I think there is a mixed feeling in the Foundation and on the Board on these points. It seems to be these documents will just throw the balance toward the abandonment option.

Mr. **Ertel.** I guess what you are saying then is you endorse the position I think Dr. Langenberg said: Basically there isn't enough here even if we put in $35 million or $40 million for science education, that there isn't enough to make a sizable impact, we ought to go to zero.

Dr. **Rutherford.** No; I am not endorsing that. The first principle I would say is survival. The science education enterprise as an identifiable part of the Science Foundation has to survive with some amount of money; $30 million or $40 million or $50 million, depending on how you use it, can do something. But the Foundation is already two or three times below the level of funding it should have. The notion that $60 million, $70 million, or $80 million is an appropriate investment in science education for this Nation is, it seems to me, patently absurd, given the size of our Nation and the nature of the problem. So sure, a little bit of money won't do much, but we have to keep science education alive. That is the first principle.

The second one is to try and get the kind of flexible support and the kind of policy that will lead to a building enterprise.

Mr. **Ertel**. Doctor, one further question. And I have got a thousand of them I could ask you, but just one. If we zero out science education as has been suggested, can you give me a parade of horribles of what can happen to our science education and to our community if we continue that with a zero now and a zero next year and a zero the year after? What do you see as the probable consequences of such an action?

Dr. **Rutherford**. What I would like to do, if you don't mind, is write you a note——

Mr. **Ertel**. I would like a parade of horribles.

Dr. **Rutherford**. Yes. I will write a letter as a private citizen on that, but let me just give you a few thoughts now. It is difficult in education with such a big enterprise to make a tight cause-and-effect chain. But I think we know some things. For example, we can believe that the people who teach science and mathematics will, in 3 years, be even less qualified than they are now because they are not getting any advanced training and it is not being provided from any other source. And there are no signs that it will improve. We can believe that the number of teachers who are qualified in the first place will continue to decline because good teachers do not like to work with colleagues who are underprepared and are not up to the job. We can believe that the resources that children have to learn with will have deteriorated even more. I believe that the last time that the schools of America, high schools particularly, were refurbished, that is to say the laboratories built and filled with up-to-date teaching apparatus in the sciences and also in foreign languages, was during the period of the National Defense Education Act. That is, when the Federal Government provided the incentive and the matching funds to promote the introduction. That has not been happening for a decade, and if we go another period of years it will get even worse.

With television like 3-2-1 CONTACT disappearing, with museums shortening hours and closing on weekends, I think we will find that few young children will be motivated to ask about science, to ask their parents questions, which will impel their parents to put some pressure on the schools and on the community. I think the trouble is going to be, Mr. Ertel, that the real deterioration won't show up quickly and dramatically as a public episode. It will just weaken and weaken and weaken the system. The public will complain more and more about the quality of education, but in a diffused manner. And when we finally discover it 2 or 3 years down the road, there is going to be another scandal, surely, as there was in the 1950's when people questioned how we allowed our schools to get in this shape. It is going to take an enormous investment to make up the difference.

Mr. **Ertel**. Thank you very much.

I didn't mean to ignore you, Dr. Hornig, but I think your interests are substantially the same as Dr. Rutherford's. You are somewhat of a more specialized subgrouping of the total issue, if I might, and the problems with women in science are certainly going to—women in the educational process will diminish if we don't have any educational program at all.

Dr. **Hornig**. That is certainly true. And I would like, if I may, to add a remark to what Dr. Rutherford just said, and that is that we are up against decreasing cohorts in the groups coming into schools already. That is, the numbers of children of high school age are already declining. That generation is just about ready to enter college. So we are up against the possibility of a really steep drop in people going into science. The combination of that demographic effect and the lack of support for science education is likely to be quite lethal.

Mr. **Ertel**. One other question that you just reminded me of. Dr. Rutherford, you said that the people who had testified previously were victims of whatever you want to make the villain, OMB, the administration, or what. Do you have any knowledge of anybody there arguing for the preservation of science education during these dramatic budgetary revisions in March or April?

Dr. **Rutherford**. I would have no way of knowing that one way or the other. I presume the arguments were made, but I really don't know. I think they are victims in the sense of a policy that is for the moment, at least, mindless, that is not based on reliable information about the situation with regard to our industrial and military status and with regard to our needs in science. And such policy can quickly do mischief and require agencies to take positions that they clearly, given their own time and instincts, were not prepared to take.

Mr. **Ertel**. Thank you very much.

Dr. **Rutherford**. Mr. Chairman, may I make one more remark?

Mr. **Walgren**. Yes, sir.

Dr. **Rutherford**. One of the ironies of the cutbacks in science education is that in the last 3 or 4 years, in both NSF and the Department of Education, there has developed finally, the basis of a research and development enterprise in teaching and learning itself. That is, we have come to support the kind of research that would help us understand how to do better teaching. Ironically, that will all disappear. The Nation's preeminent research institution is now saying that it will not fund research on science learning.

Mr. **Ertel**. Mr. Chairman, I would ask unanimous consent that when Dr. Rutherford provides his letter in response to my question, that it be made a part of the record.

Mr. **Walgren**. Without objection.

[The letter mentioned above follows:]

*American Association
for the Advancement of Science*

1776 MASSACHUSETTS AVENUE, NW, WASHINGTON, D. C., 20036

Phone: 467-4400 (Area Code 202) Cable Address: Advancesci, Washington, D. C.

March 17, 1981

Congressman Allen E. Ertel
Committee on Science, Research & Technology
2319 Rayburn House Office Building
Washington, D.C. 20515

Dear Congressman Ertel,

Your question to me at the hearing on March 10, 1981, was: What would be the practical consequences of zeroing out the NSF science education budget, even if, after two or three years, a gradual restoration was begun? Since NSF currently exerts what little national leadership there is in science, mathematics and engineering education and provides most of the tiny federal funding directed toward science education, your question might be recast as: What will happen if the federal government makes no attempt during the next few years to help stem the steady deterioration in the quality of science education in our country at the very time that all of our competitors are strengthening theirs?

My response consists of two parts. First are listed what I believe will be the major consequences of federal abandonment of science education; then I briefly outline the context in which those conclusions are imbedded.

Consequences

1. The size of the pool from which future scientists and engineers will be drawn will be severely reduced. By 1995 the proportion of the total population in the 18-24 age range will be 25 percent less than it is in 1980. If, as we approach the end of this century, the number of scientists and engineers is not to decrease in absolute terms--let alone increase to meet what by then will be an increasing industrial and military demand--the proportion of this population prepared for higher education in science and engineering must increase. But if federal science career motivation programs are cut off, we can expect a smaller proportion, and hence a much smaller number of young children to be attracted to science and engineering careers in the first place. Saturday Science Academies, a relatively new NSF-supported activity, introduces hundreds of elementary school minority children to the excitment of science and mathematics every Saturday. 3-2-1 Contact, the TV science program for 8 to 12 years olds, reaches millions of youngsters in-school and out, some of whom have no other way to learn what fun science can be. Summer research in university laboratories provide the first opportunity scientifically talented high schoolers have to do real research, an experience that in the past has led many to commit themselves to a life of science. Cut out these activities and you can be certain that each year thousands of young people will have lost the only chance they

might have had to be drawn to science--to become, as it were, part of "the pool of future scientists." And so the pool will shrink.

And then shrink some more, for many of those children who do become interested in science when very young will be turned away by the poor quality of science teaching they encounter in their junior and senior high schools. Without federal help, science and mathematics teaching can only get worse. Without federally funded in-service institutes, high school science and mathematics teachers will fall further behind in their subjects, and their already damaging isolation from on-going contact with research and the real world of science will be made more complete. Every single year this persists will be a year that hastens the increasing shortfall of scientific human resources.

2. New entrants into the nation's technical and managerial work force will, in the aggregate, be increasingly underprepared to function effectively. Even now the schools are failing to turn out graduates who can cope with the increasingly technical nature of work in commerce, industry and the military. To allow the situation to become still worse by withdrawing the only federal effort that addresses, however timidly, the educational roots of our productivity/security concerns, is, at best, to incur enormous national (if not federal) costs, and at worst, to court disaster. Each year that the system fails, the "educational national debt" grows, ultimately to be paid by the public. Industry and the military must provide science

and mathematics education to make up for school failures, the heavy costs to be passed on. To the extent that our business and defense establishments are unable to rectify previous science education failures, productivity lags further, inflation worsens, public costs soar. The effect is cumulative. Each year that we let this problem go unattended by national leadership and resources, we mortgage the economy, and face the unhappy, totally unnecessary prospect in a few years of either investing in expensive "re-education" or paying the price of ill-prepared workers year after year.

3. Social mobility will be stifled. Education has long been regarded by Americans as the way to improve one's station in life. We have long believed that if you get a good education you will get a good job, that is, a job that pays well and has status. Even though in truth not all Americans have had the same opportunity for "a good education," it is still the guiding priciple in a free economy. Increasingly, the kind of education that provides a chance for advancement in our society is a technical one, one based firmly on a sound education in science and mathematics. This is precisely, however, where education of the disadvantaged--the urban and rural poor and ethnic minorities--and of women is the weakest.

NSF programs to address the underrepresentation of women and the disadvantaged in science constitute not only the nation's main effort to increase the science talent pool, and conserve human resources, but also its best effort to keep persons in those groups from being shut out of full participation in our culture. To stop abruptly programs that have taken years to design and get underway, even if the hiatus were only for a year or two, would be to sacrifice momentum that has taken over a decade to build, and to retreat from serious federal participation in sensible efforts to prepare the disadvantaged for upward mobility in the world of tomorrow.

Context

In educational and social matters it is difficult to predict in quantitative terms and with absolute certainty just what the effect will be of any particular action or inaction. This is so whether one is speaking of nationwide programs or the individual classroom. Nevertheless, by reflecting on previous experience with federal programs in education and thoughtfully examining current national needs in relation to human and material resources, it becomes possible to project with considerable confidence the qualitative conclusions presented above. In order to place those conclusions in a practical context of national concerns and human resources, I believe it would be helpful to note some features of that context.

1. The immediate and long-term needs in the United States are to strengthen our national well-being and re-establish our position of world leadership. This will come through improvement of our economy, increases in our productivity, strengthening of our defense, and raising the morale and sense of well-being of our population. There is no controversy about these broad goals.

2. The supply of highly educated people is a decisive factor in accomplishing these ends and in the international competition (commercial and military) for leadership, perhaps even for survival. This is particularly true in science and technology education, because science and technology clearly play the central role in addressing our national economic and security aims.

3. Science and engineering education are in trouble in this country: As the supply system for the scientific and technological enterprise, it is deteriorating, becoming weaker and weaker at its very origins; as the builder of a general public prepared to function in a democratic, technological society, it is nearly bankrupt. This double failure is all the more disconcerting in view of the fact that Great Britain, France, the Federal Republic of Germany, Japan, the Soviet Union and many other technologically based societies quite evidently attach much more importance to school science and mathematics education than we do and are striving to attain an ever high level of technical competency in the general population.

4. Ours is a non-centralized system of education in which practical responsibilities are shared among local, state and federal agencies and public and private institutions. In the domain of scientific and technical education the federal government has historically played an important, often unique, and certainly key role in support of state and local efforts. There is no reason at all,

quite the contrary, to believe that financially strapped schools, states or universities--which is to say almost all of them!--will now pick up the costs of assuming those roles which since the late 1950s have been considered "federal" by all concerned. Current structural weaknesses in our collapsing science education edifice, far from being shored up or repaired, will quickly be made weaker by the elimination of the NSF Science Education Directorate. Just consider the following:

- Science and mathematics teachers from junior high school through undergraduate levels are falling behind in knowledge of their subjects. NSF has a long and highly regarded history of generating carefully targetted training opportunities for science teachers at all levels, covering all of the scientific disciplines and engineering fields, running from a few days to a few weeks, and involving the nation's best research scientists in sharing with their teaching colleagues. Schools and colleges have never provided such continuing education on their own, nor will they, for they lack the resources, the incentive structure and the connections to the total scientific community.
- Most young children have very few opportunities in school or out to become attracted to science. Only NSF has been able to mobilize public and private sector resources to

reach out to young people. 3-2-1 Contact is but one example of the NSF's ability to marshall industrial resources as well as those of other agencies on behalf of children and the nation's well-being. Cut science education at NSF and all such children programs will disappear immediately.

o Demand for advanced training in science, mathematics and engineering is not rapidly responsive to the market, and imbalances can develop, as has been documented in Science and Engineering Education in the 1980's and Beyond. Only the federal government can mount, monitor, and adjust a program of graduate scholarships (fellowships and/or traineeships) to encourage some of the most talented college students to pursue graduate training in fields of science and engineering where the national needs are greatest. As NSF has successfully shown, such an effort must focus on identifying and helping students of only the very highest quality, "competence" not being sufficient, nor financial need the main criterion. Without this, a fair share of the brightest students will not end up in science and engineering, instead electing careers having greater immediate rewards than the rigors of graduate study.

o Teaching science requires facilities and equipment that reflect the real world of scientific research. At every level today, science teaching facilities are out of date and in many schools and colleges simply worn out. The replacement of our obsolete and decripit inventory of science instructional equipment will be expensive but must be undertaken on a shared basis. The past shows that (1) NSF instrumentation dollars are able to bring out institutional and industrial funds, and (2) without federal support up front, it is nearly impossible to secure other funds. To discontinue NSF support now would be to accelerate the already rapid demise of laboratory-based science teaching.

o Science and mathematics education, like all large scale, complex and expensive undertakings, needs to exploit the new and developing information and communications technologies if it is to improve and become more efficient. This means R&D applied to science education. With guidance and support from NSF, research in science education is beginning to show positive results. Without NSF, there will be nowhere to turn, for local schools lack the human and financial resources to conduct such research, as do most states. And what little R&D is done without federal support is rarely of interest outside of the particular location where it is done.

5. Finally a word on the uniqueness of the NSF role in science education. Looked at in strictly dollar outlays, the Science Education Directorate effort appears tiny. The country spends over a hundred billion a year on education, the NSF a few million. But that comparison deceives us, for it misses the nature of the agency's special role. The energy of a pilot light or match is also small compared to that of a furnace, but without it there may be no heat.

Anyone proposing to eliminate the partnership between science research and science education at NSF, a partnership highlighted in the Foundation's conception and supported by seven presidents and 15 Congresses, should consider the following:

- A NSF science education effort of reasonable magnitude constitutes the single most important symbol of the federal governments recognition of the importance of science education in a society whose welfare is based on the fruits of scientific and technological pursuits.
- It provides the only leadership there is that can focus attention on problems of science education crucial to the welfare of the nation's citizens.
- By setting an example and establishing some financial incentives, it motivates state, local and private institutions to address problems in science and mathematics that they otherwise would sidestep, and stimulates them to invest their own resources.

- It builds linkages, vital to the health of science and engineering education, between science teachers and scientists and engineers.
- It does some things in science education--supporting R&D, funding teacher training workshops, providing graduate scholarships to outstanding students, etc.--that otherwise are likely to be left undone or to be done badly.

In short, Congressman Ertel, the question should be: How can we turn the tide? For more than a decade science and engineering education has been badly underbudgeted at NSF and starved throughout the entire country. The dismal results of this national folly are now plain to see. Until the health of science education is restored, talk of revitalizing our economy, increasing our productivity, and establishing again our world leadership in science and technology is but wind in the willows. Given a mandate, Congressional guidance and a sensible budget, NSF could help the nation get going again.

Sincerely,

F. James Rutherford

Mr. **Ertel**. Thank you.

Mr. **Walgren**. Thank you, Mr. Ertel.

I wanted to ask perhaps both of you if you have experience, about whether or not in the area of science education we have mandated too many specific programs so that we ought to move to a block grant type of funding in that area that the National Science Foundation could use with greater flexibility. Would that be more helpful?

Dr. **Rutherford**. Well, some flexibility would surely be helpful. I think, in recent years the Congress has gotten much too busy trying to specify in detail just how every bit of money is to be spent. On the other hand, those programs of NSF can be thought of as simply mechanisms, as titles that represent either an area of interest or a particular function. In that regard, the right programs are about there. I do not believe the charge that there is all that overlap and confusion. There are programs that focus on the quality of elementary and high school teachers; there are programs that focus on upgrading the quality of college, particularly undergraduate teachers. There are other programs that focus on what has to be done to help minorities and women have a larger part in the scientific enterprise. There are those programs that try to develop new knowledge and new programs and ideas, R. & D. programs. There are those that try to help the institutions, particularly the undergraduate institutions that desperately need to have their faculty upgraded and need some help in reforming their own curricula. So there are sets of programs around, Mr. Chairman, that I think are approximately the right ones even though, of course, they could be streamlined in some internal reorganization. I guess I take an intermediate position: When you provide funds, have fewer hooks on them but specify the areas of attention, that they must pay attention to the access question of minorities and women and must show you the programs that will do it, and to the younger children and to the public outside of the schools and colleges.

Mr. **Walgren**. I see.

Dr. Hornig, do you have a response to that?

Dr. **Hornig**. Yes. I would like to support Dr. Rutherford's last point. I realize the problems involved in having too many directives about how you use your money and cutting that up into too many small pieces. On the other hand, I think it is true that NSF probably would by its own preference have paid no attention whatsoever to early science education programs and to programs on behalf of women and minorities. One reason I say that is that its very first response to the Science and Technology Equal Opportunities Act which in fact mandated a very broad range of programs—the very first response was to institute two programs, much needed ones, I agree, but they are at the advanced professional level. They really have only indirect effect on education, and they are designed that way. This really becomes another way of allocating research funds, and I think the foundation would prefer to use education money that way. I am a strong supporter of basic research and highly advanced training. We must have that to the fullest extent that we are able to provide it. But it has to be in some reasonable balance with early education. We can't simply go on educating first predoctoral fellows and postdoctoral fellows, then we have post-postdoctoral awards and then we have senior career development awards at some later stage and we end up supporting one group of highly meritorious, highly advanced people. That is wonderful if you can afford it forever, but we are not providing the flow of new recruits to those fields that we need, and they will wither on the vine eventually without that.

[Response to additional questions submitted by Mr. Scoville follows:]

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March 17, 1981

Rep. Don Walgren
Chairman
Subcommittee on Science, Research,
and Technology
U.S. House of Representatives
2321 Rayburn Bldg.
Washington, D.C. 20515

Dear Mr. Walgren:

Thank you again for the opportunity to testify at the NSF budget hearings on March 10. I am happy to submit for the record the following statement in response to the additional questions transmitted by Mr. Scoville.

1. The impact of the proposed cuts in research funding for social and behavioral sciences would be disproportionately severe on women scientists as a group. Women now earn one third of all Ph.D.s in these fields, and since the proportions of women in physical and natural sciences are lower, 55% of all women's science and engineering Ph.D.s go to women in social and behavioral sciences. Conversely, male social and behavioral science Ph.D.s represent only 30% of all new male science doctorates. The proportional effect of the proposed cuts in these fields would therefore be nearly twice as great on women.

In addition, many of the women in these fields (as well as the men) carry on research on women in their specific disciplines, on a great variety of topics including such things as women's labor force behavior, educational persistence and choices, and career advancement. Studies of this sort need to be encouraged to provide realistic data for national policy planning. As an example, a study of the effects on the science and technology workforce of various policy alternatives for increasing military manpower which the Commission on Human Resources recently commissioned did not take into account the growing participation of women in science. If one factors this in, the effect of a military draft on the flow of young scientists and engineers can be cut approximately in half. Clearly, planning, for industrial and other needs must also begin to take account of such considerations. Unless social science research on women is supported, the bases for decisions will not exist.

2. Assuming that some proposed cuts can be restored, my priorities for where the funds could best be used would shift somewhat with the amount available. One of my few points of agreement with Dr. Slaughter is that funding a few projects at an adequate level is preferable to spreading the same amount of money so thin as to virtually insure failure. Currently, I believe the most urgent priorities in the Science Education Directorate are in three areas: 1) adequate training of school science and math teachers including

in-service support such as regional science resource centers, and 2) program-oriented research on improvement in science education including curricular materials and methodology. Both types of program should require special attention to the needs of underrepresented groups. 3) Support to update obsolete instrumentation and equipment for undergraduate science. This is a much larger budget item than the other two. The need for such a program was documented extensively in the study of science education carried out a year ago for NSF by the Commission on Human Resources. Current graduates in engineering and physical sciences must go into industry and research with inadequate experience and training in handling the tools of their trade.

3. With respect to your question about the effects of the Science & Technology Equal Opportunities Act (S.568) on the proposed cuts, the Conference Report (Nov. 21, 1980) "provides that of the sums appropriated to the Foundation...not less than $30,000,000 total shall be available in fiscal year 1981 for all the activities...relating to women and minorities in science." The Report also expressed expectation that funds would be allocated from various programs and particularly that "the Science Education Directorate not be adversely affected out of proportion to other directorates". Thus it seems to me that the proposed cuts, which would eliminate all of the minorities and women's programs in addition to other science education efforts, directly contravene the expressed intent of the Congress. Minimal compliance with the Act would require only proportional cuts rather than total elimination, and an effort to spread the mandated programs among the research directorates. Certainly the two recently announced programs could be allocated among research directorates at least as logically as to Science Education, since their major purpose is research career development. Last year when I testified in the Senate on these issues, Director Atkinson argued that NSF wanted to phase out targeted programs for women and minorities and replace them with a broad-scale emphasis on equity throughout all Foundation directorates. I responded at the time that while that was a desirable long term goal, NSF should first begin to build the capability to handle such an effort. To my knowledge that has not yet happened; compliance with the provisions of S.568 would at least move in that direction.

Finally, let me restate my conviction that eliminating funds for science education would damage very seriously our scientific and technological capabilities in the near future, and that such damage could not be repaired quickly if the cuts were to be restored at some future time. It is not simply a matter of a necessary educational sequence being interrupted; it is also that such cuts would send a clear message to our young people that the nation considers science unimportant and that they need not pay attention to it either. Our competitors abroad would also conclude that we are very short-sighted and don't know where our best interests lie.

Thank you again for this opportunity to make my views known.

Sincerely yours,

Lilli S. Hornig

Lilli S. Hornig
Executive Director

cc: Rep. Margaret Heckler
Mr. Anthony Scoville

Mr. **Walgren.** Thank you very much.

I want to particularly express Mrs. Heckler's appreciation for your coming, Dr. Hornig. And Dr. Rutherford, we certainly appreciate you being here and what you have contributed to the hearing. Thank you both.

The next and last panel is made up of Dr. Robert Marston, the president of the University of Florida, who is testifying for the Association of American Universities. Also Dr. Arliss Roaden, who is the president of the Tennessee Technical University, testifying for the Americal Association of American Colleges and Universities, and Dr. William Powell, vice president and provost of Oberlin College, testifying for the Great Lakes Association of Independent Colleges.

Let me say at the outset, Dr. Roaden, that Congressman Gore had hoped to be here to particularly welcome you to the committee and has prepared some remarks of his own that without objection we will put in the record.

[The prepared remarks of Congressman Gore follow:]

Introduction of Dr. Arliss Roaden by Congressman Albert Gore, Jr.

Mr. Chairman, I want to thank you for the opportunity to introduce your next witness.

Not only is Dr. Roaden an eminent educator and administrator, but he has worked hard to serve as a bridge between the nation's colleges and universities to this legislative body. As a result, the Congress, through the leadership of this Committee, has adopted an aggressive policy of Federal support for science education.

We are entering an unprecedented era of reindustrialization with a critical shortage of trained engineers and scientists to man our new industrial effort. Through a careful, consistent policy of funding for science education throughout the country, we have begun to build the kind of basic framework for producing the highly-trained manpower we must have if this massive reindustrialization effort is to succeed.

Unfortunately, this Administration has proposed to reverse that process, in effect killing this basic support so desperately needed by our colleges and their science students, and the industries they will serve.

Dr. Arliss Roaden comes before this Subcommittee exceptionally qualified to discuss this problem. He is currently Chairman of the Commission on Science and Technology within the American Association of State Colleges and Universities, and is the Tennessee representative for that organization. Today he is also representing the American Council on Education.

Dr. Roaden is better known to us in Tennessee as the President of Tennessee Technological University in Cookeville. He has served in that important capacity for seven years. For 12 years before coming to Tennessee he was Professor of Education at Ohio State University and also served as Dean of the Graduate School, and Vice-Provost for Research at that University.

I am extremely proud to have Dr. Roaden as my constituent. I have learned a great deal from him during my service in Congress, and I know the Subcommittee will benefit from his testimony.

Thank you.

Mr. **Walgren.** We will start with Dr. Marston, and any written statement that you have will be made a part of the record as a matter of course, and at this time of the day summarizing it, providing it is as complete as you want to, would be appreciated.

Thank you, Doctor.

[A biographical sketch of Dr. Marston follows:]

Dr. Robert Q. Marston
Biographical Sketch

Dr. Robert Quarles Marston, the seventh president of the University of Florida, has spent his professional life in medicine and education. He was Associate Director of the National Institutes of Health and Director of the Division of Regional Medical Programs, 1966-68; Director of the National Institutes of Health, 1968-73; Dean of the College of Medicine of the University of Mississippi, 1961-65; Vice Chancellor of the University of Mississippi 1965-66; and a member of the faculty of the Medical College of Virginia, 1954-57 and 1959-61, and the University of Minnesota, 1958-59.

Dr. Marston was educated in the Virginia Military Institute (B.S.-1943), Medical College of Virginia (M.D.-1947) and as a Rhodes scholar at Oxford University (B.S.-1949). He also received training at Johns Hopkins, Vanderbilt and the National Institutes of Health. He came to the University of Florida August 1, 1974, from positions as scholar-in-residence at the University oif Virginia and as a distinguished fellow at the institute of Medicine of the National Academy of Sciences.

In addition to being a Rhodes scholar, Dr. Marston has been honored as a Markle scholar; a member of the Society of Scholars, Johns Hopkins University; and a fellow (honorary) of Lincoln College, Oxford. His honorary Doctor of Science degrees include one from the College of William and Mary in the area of his birth. A member of several professional societies, he is a distinguished service member of the Association of American Medical Colleges, an honorary member of the National Medical Association and the American Hospital Association, and a member of the Association of American Physicians and the Institute of Medicine of the National Academy of Sciences and a member of its governing Council, Chairman of the Board of Visitors of Air University, and serves on the Executive Committee of the National Association of State Universities and Land-Grant Colleges.

Dr. Marston served as a First Lieutenant in the United States Army. He was born in Toano, Virginia, in 1923 and he and his wife, Ann have three children: Ann Wright Peace, a medical technologist living in Richmond, Virginia; Robert D., Curate, St. Stephens Episcopal Church, Culpeper, Virginia; and Wes, a student at the University of Florida.

STATEMENT OF DR. ROBERT Q. MARSTON, PRESIDENT, UNIVERSITY OF FLORIDA

Dr. **Marston**. Mr. Chairman and members of the committee, my name is Robert Marston and I am president of the University of Florida. I am pleased to have this opportunity to present to you views on the science and engineering education needs of the Nation as they are addressed by the fiscal year 1982 budget of the National Science Foundation. My statement is being presented on behalf of several higher education associations: the American Council on Education, the Association of American Universitites, the Association of Graduate Schools, the Council of Graduate Schools in the United States and the National Association of State Universities & Land-Grant Colleges. The universities and colleges represented by these associations carry out over 50 percent of all federally funded basic research programs. They are the source of virtually all of our Nation's scientists and engineers. In addition they produced the many elementary and secondary level teachers and administrators who play such an indispensable role in the science of this Nation.

The National Science Foundation has a vital role in leading the Nation's investment in basic research and science education. The Foundation's research programs provide more than 34 percent of Federal support for basic research in our universities and colleges. Unlike other Federal agencies, such as the Departments of Defense, and Energy, or NIH, the Foundation maintains no laboratories of its own. All National Science Foundation research and education programs are carried out by universities, colleges and other non-Federal organizations. It has, in fact, been outstanding in its own experiments in designing better modes for the prosecution of research at universities. The Materials Research Laboratory concept of block grants—and you brought that up several times this morning—has been an outstanding success. The current American Association of Universities/National Science Foundation experiment in grants administration, which is now being tested on our campus among others, gives universities greater flexibility in fiscal matters, has increased the efficiency of research, eliminated unnecessary reporting and gives every indication of being another large step forward in grant adminstration. The National Science Foundation truly occupies a unique place in our society.

This hearing does occur at a singular time in our history, when a new administration is now beginning to establish its priorities and policies for a nation which is troubled in many ways, and a new Congress is weighing responses to it. I trust that this will be against the background of the broad bipartisan agreement on and commitment to the need to sustain the Federal responsibility and investment for research and training, particularly in the basic sciences and engineering.

Indeed, in the period roughly since the end of the Second World War, a consensus has been forged in this country that research and training for research are indeed indispensible elements to our health, economic prosperity, cultural vigor, and military strength. It has been understood that some of the most extraordinary discoveries are not fully appreciated until long after they are first made. Ultimately, it is also agreed that the entire Nation shares in the fruits of research, and that the costs to society of modern research cannot be met without a substantial and diversified Federal contribution.

The most visible sign of this consensus has been the growth of a group of research universities whose performance in research and training has been a triumph of American public policy and which remain, as a group, the unduplicated envy of the world. It is difficult to think of an achievement in science and technology during this entire period that does not bear the mark of the work done in one or more of these institutions. And you know many of the examples.

For example~~, there~~ were only 20 of 142 Nobel Prizes awarded to people in this country prior to World War II in the sciences of chemistry, physics, physiology, and medicine, while between 1945 and 1978 American scientists received 94 of the total of 184 prizes awarded. And there are many other evidences of the result of the investment that has been made during this period of time.

In defense, our current superiorities in the technologies of missile guidance, advanced aircraft, submarines, and space defense systems rest on a foundation of research built up over the last decade or more. Now if we are to retain our lead in critical areas and remain competitive in the world marketplace, additional work is needed in fields such as computer sciences, materials, and advanced electronics. The stream of knowledge needed to keep pace with the competition cannot be turned off and on at will. Unless new, stronger foundations are laid in the 1980's by people trained to a new level of excellence, there will be no way to meet the needs of the 1990's.

The storing up of information and replenishing the bank of information is the primary mission of the National Science Foundation. It is in fact the only major Federal agency of the Federal Government which has as its primary mission the support of fundamental science. It is for that reason that the National Science Foundation in its 30-year history has made historic contributions to science and to the Nation.

The Nation's universities bring to the research enterprise a strong commitment to independent thinking, an increasingly robust interdisciplinary environment, and a mutually supported relationship between research and training. Together these reward an investment in research in the universities with multiple benefits: research is accomplished in an unusually conducive atmosphere while those who will become the research leaders and teachers of later years are instructed and encouraged as their fresh ideas nourish the enterprise.

I want to say just a word about the need for stable support. We have had for many years now up-and-down support in many areas. The University of Florida has as its priorities in the use of State funds investment in engineering, physics, and the biological sciences. This really is the result of the old centers of excellence of the National Science Foundation 10 and 15 years ago. When we began building up strength in these areas, the programs went out of existence, but universities have to think in terms of decades. We continued to build strength in these areas, and more recently, with help from the State legislature, have increased the strength in areas stimulated first by Federal funds and by a particular program.

Clearly the decades ahead will call for greater, not less investment in science and technology. Surely there is agreement on that. We will require stronger, not weaker, science and technology; more, not fewer, educated people to sustain our pursuit of solutions in many, many areas. Research and education go hand in hand, and I have in my prepared statement some comments on that, but that has essentially been discussed this morning, so that I will leave that for the record.

There is an area that has not been stressed that was touched on recently in some of the testimony, and that is the need for instrumentation and equipment. And I will leave one document with you. It is a report to the National Science Foundation by the Association of American Universities entitled "The Scientific Instrumentation Needs of Research Universities." The same type study is being done on the research facilities needs and shortly we will have a companion report which will speak to these needs.

[The executive summary of the referenced report follows Dr. Marston's prepared statement. The complete report is available in the subcommittee's files.]

One cannot do the type of science that is required today with deteriorating equipment and instrumentation in our laboratories. It has been estimated that there is a twofold difference in the age of equipment in comparable science laboratories in universities compared to industry doing similar types of work. We have had 15 years of neglect in replacing this equipment, and they have left their mark. It will be costly, and the figures are large if we are to make up for the failure to keep that equipment up to date. The problem is large and serious. It requires especial attention of this committee, the Government, of industry, and of the universities.

Thank you, Mr. Chairman, for the opportunity to present these views to the committee, and I will be pleased to respond to your questions.

[The prepared statement of Dr. Marston follows:]

TESTIMONY
on the
FY 1982
AUTHORIZATION
for the
NATIONAL SCIENCE FOUNDATION

before
the
Subcommittee on Science, Research & Technology
of the
Committee on Science and Technology
U.S. House of Representatives

by
Robert Q. Marston
President, University of Florida

on behalf of the
American Council on Education
Association of American Universities
Association of Graduate Schools
Council of Graduate Schools in the United States
and
National Association of State Universities and Land-Grant Colleges

March 10, 1981

Testimony before Subcommittee on Science Research & Technology of the House Committee on Science & Technology

Mr. Chairman and members of the Committee:

My name is Robert Marston and I am President of the University of Florida. I am pleased to have this opportunity to present to you views on the science and engineering education needs of the nation as they are addressed by the FY 1982 budget of the National Science Foundation. My statement is being presented on behalf of several higher education associations: the American Council on Education, the Association of American Universities, the Association of Graduate Schools, the Council of Graduate Schools in the United States and the National Association of State Universities and Land-Grant Colleges. The universities and colleges represented by these associations carry out over 50% of all federally-funded basic research programs. They are the source of virtually all of our nation's scientists and engineers. In addition they produce the many elementary and secondary level teachers and administrators who play indispensible roles in scientific education of our people.

The National Science Foundation has a vital role in leading the nation's investment in basic research and science education. The Foundation's research programs provide more than 34% of federal support for basic research in our universities and colleges. Unlike other federal agencies, such as the Departments of Defense and Energy, the Foundation maintains no laboratories of its own. All NSF research and education programs are carried out by universities, colleges and other nonfederal organizations. NSF has, in fact, been outstanding in its own experiments in designing better modes for the prosecution of research at universities. The Materials Research Laboratory concept of block grants has been outstandingly successful. The current AAU/NSF experiment in grants administration, which is now being tested on our campus among others, gives universities greater flexibility in fiscal matters, has increased the efficiency of research, eliminated unncecessary reporting and gives every indication of being another large step forward in grant administration. NSF truly occupies a unique place at the wellsprings of our society.

Why Research and Science Education

This hearing occurs at a singular time in our history. A new administration now is beginning to establish its priorities and policies for a troubled nation and a new Congress is weighing responses to them. It is an important moment for all of us, one which demands that we give very careful consideration to the many ways in which our nation is dependent upon the quality and vitality of our national capacity for science research and education and the extent to which that capacity is dependent on the nature and level of national investment made through the Federal government. The National Science Foundation, and this Committee in its role as overseer of the Foundation, perform crucial roles in exercising stewardship of that investment.

In recent years, there has been broad bi-partision agreement on and commitment to the need to sustain the federal responsibility and investment for research and training, particularly in the basic sciences and engineering. That commitment is essential if the United States is to remain at the forefront in the discovery and the application of new knowledge, be a world leader in science and technology, retain our position in the world marketplace and provide for our national defense. Were our national resolve in this effort not sustained, or were it to experience severe or sudden dislocations, the price we as a nation will pay in foreseeable and unforeseeable ways will be enormous.

As we begin a new debate on national priorities and problems it is perhaps well for us to recall something of the history of the federal role in basic science and education and the extent to which the country is fundamentally dependent upon them.

In the period roughly since the end of the Second World War a consensus has been forged in this country that research and training for research indeed are indispensible elements to our health, economic prosperity, cultural vigor and military strength. It has been understood that some of the most extraordinary discoveries are not fully appreciated until long after they are first made. Ultimately, it also is agreed, the entire nation shares in the fruits of research and that the costs to society of modern research cannot be met without a substantial and diversified federal contribution.

The most visible sign of this consensus has been the growth of a group of research universities whose performance in research and training has been a triumph of American public policy and which remain, as a group, the unduplicated envy of the world. It is difficult to think of an achievement in science and technology during this entire period that does not bear the mark of work done in one or more of these institutions.

The results truly have been remarkable. For example, scientists from the United States received only 20 of 142 Nobel prizes awarded prior to World War II in the sciences: chemistry, physics, physiology, and medicine. Between 1945 and 1978 American scientists received 94 of the 184 prizes awarded.

Another example which highlights the importance of flexibility of basic inquiry is a study by the National Science Foundation of the 85 most significant advances over the past 20 years in four scientific fields (mathematics, chemistry, astronomy and the earth sciences). University scientists were found to have been responsible for more than 70% of them. Perhaps a more significant finding was that only 43% of the projects which led to these advances had actually contained in the funding proposal a direct reference to the significant outcomes. Forty percent of the advances derived from grants for broad research in the general area, and 17% were related neither directly nor generally to the justification used for requesting support. These findings are especially significant as we think about our nation's imperative need to find new ways to increase our industrial productivity, strengthen our defense, meet our energy needs and address other pressing problems ahead.

Out of exploratory research have come such important discoveries as antibiotics, computers, bio-technology, nuclear energy and lasers. Studies conducted years ago by geologists interested in cataclysmic environmental changes in the ancient world suddenly have taken on new meaning as companies try to locate additional oil deposits. Current efforts to harness the power of nuclear fusion can be traced back to a fundamental interest in the nature of the stars and the origins of the universe. We now have CAT scanners in hospitals because some people thirty years ago were doing basic research in solid state physics.

In defense our current superiorities in the technologies of missle guidance, advanced aircraft, submarines, and space defense systems rest on a foundation of research built up over the last decade or more. Now if we are to retain our lead in critical areas and remain competitive in the world market place additional work is needed in fields such as computer sciences, materials and advanced electronics. The stream of knowledge needed to keep pace with the competition, cannot be turned on and off at will. Each discovery builds on earlier discoveries, often in unpredictable ways. Unless new, stronger foundations are laid in the 1980s by people trained to new levels of excellence, there will be no way to meet the needs of the 1990s.

In the area of health, Dr. Lewis Thomas, President of Sloan Kettering Memorial Hospital has noted that it required

50 years of concentrated basic research to pave the way for antibiotics. "Without the long painstaking research on the bacillus," he has written, "we would be thinking that tuberculosis was due to night air and we would still be trying to cure it by sunlight. We need reminding now more than ever that the capacity of medicine to deal with infectious disease was not a lucky fluke; nor was it something that happened simply as a result of the passage of time. It was the direct outcome of hard work done by imaginative and skilled scientists...It was basic science on a very high order, storing up a great mass of interest and knowledge for its own sake, creating so to speak, a bank of information ready for drawing out when the time for intelligent use arrived."

The storing up of information and replenishing the bank of information described by Dr. Thomas is the primary mission of the National Science Foundation. It is in fact the only major federal agency of the Federal government which has as its primary mission the support of fundamental science. It is for that reason that the National Science Foundation in its 30-year history has made historic contributions to science and the nation.

Just as basic research can yield new fundamental knowledge so too can applied research yield such new knowledge. Irvin Langmuir won a Nobel Prize in chemistry for work which began as an effort to improve lightbulbs. Arno Penzias and

Robert Wilson detected microwave radiation from the origin of the universe using a radio antenna designed for use in developing satellite communications.

The nation's universities bring to the research enterprise a strong commitment to independent thinking, an increasingly robust interdisciplinary environment, and a mutually supported relationship between research and training. Together these reward an investment in university research with multiple benefits: research is accomplished in an unusually conducive atmosphere while those who will become the research leaders and teachers of later years are instructed and encouraged as their fresh ideas nourish the enterprise.

Our universities can remain in the forefront of the advancement of science and technology; they can conduct the fundamental research which adds to the store of knowledge, they can prepare the scientists, engineers and teachers for future generations (for service in industry, government and private laboratories as well as universities and other educational institutions) only if they have both substantial and stable assistance in meeting the inexorably rising costs of research and education; i.e., costs for skilled personnel, materials, facilties, and increasingly sophisticated research instrumentation and equipment.

A Stable Investment Policy is Essential

If the National Science Foundation is to continue to lead the nation's search for new knowledge, and if we are to educate the scientists, engineers and teachers in the numbers and specialties the nation needs, we must consider several inescapable facts. The first is that a research and education enterprise requires time to become productive. It requires the foundation provided by a stable investment policy that protects it from sharp and disruptive changes, such as those now proposed for certain Foundation programs.

For several years, beginning with President Ford's administration, the Federal government has sustained an effort we fully supported to reverse the decline in federal support for basic science. Now the Administration's effort to address our pressing economic problems includes proposals to impose real and substantial reductions across the spectrum of NSF research and related science education programs. We understand that the Administration today proposed reductions in the Foundation's basic research programs plus even deeper cuts in some areas, especially in science education and the social and economic sciences. If they are approved, such reductions will have a damaging and disruptive effect on our nation's research and education enterprise disproportionate to the relative small savings that may be achieved. For the following reasons we urge the Congress to reject attempts to subject the nation's investment in the Foundation's education and research programs to such sharp and ill-considered reductions.

Some assert that science education and the continued development of the social, economic and behavioral sciences ought to have less importance to our nation now than the physical sciences and engineering. We disagree with that view. All of these fields, are in fact, closely linked, and our society is deeply dependent upon them.

The United States achieved world leadership and became the major source of discovery, invention and innovation because modern technology, much of it generated by sustained federal investment, has made tremendous and well known strides. We now are at a point in our development where we need to sustain our future technology growth while at the same time extending our society's capacities to understand and manage it. Our ability to understand and to cope with the very difficult social, behavioral and economic questions which rapid progress inevitably brings has fallen behind the necessary pace of technological development. While continuing to strive for scientific advancement, we better need to understand, recognize and take cognizance of the second order efforts and broad consequences of that scientific and technological growth.

Clearly the decades ahead will call for greater, not less investment in science and technology. Surely there is agreement on that. We will require stronger, not weaker, science and technlogy, and more, not fewer, educated people to sustain our pursuit of solutions to the energy, defense, food, health, education and economic problems we face. In developing our understanding of our nation's incredibly complex economic structure and the world marketplace we will need more, not less, penetrating and sophisticated economic analyses and research.

Therefore, it is inconceivable that the Administration seriously proposes, in effect, to move toward termination of support for the Foundation's research programs in the economic and social sciences. At a time when government is steadily adding to its inventory of econometric models to deal with the burgeoning interest in supply side economic modelling, it seems quite contradictory to have the basic science programs that underpin the development of such tools, in effect, terminated. Rather than curtail the federal investment in these areas we would recommend greater attention to the pursuit of excellence in them. We urge the Committee to reject the administration's proposals and to take the steps necessary to insure that the nation will continue a balanced investment in the pursuit of excellence in these areas as well as in the physical sciences and engineering.

The Nation Needs More Highly Trained People

In addition to requesting substantial reductions in these areas, we understand that the Administration proposes to terminate the entire science education activity of the Foundation. To this we must strenuously object, and we urge the Congress to reject such steps as short-sighted budgetary expediency. This is a clear case of the budget tail wagging the dog.

The proposal strikes directly at the heart of the Foundation's charter. Since it was created in 1950, NSF has had the duel mission of supporting excellence in research and in science education. As recently as a year ago, in creating the Department of Education, the Congress reaffirmed the importance of retaining a vigorous comprehensive science education activity as part of the Foundation. The Congress specifically rejected proposals to move science education from NSF to the Department.

Were all science education programs eliminated from the Foundation, irreparable damage would be done to the education of future generations of scientists, engineers and teachers. The Science Education Directorate provides the focus for the continuing development of programs and iniatives designed to address the well-documented shortcomings of our nation's schools, colleges and society at large. The recent report by the NSF and the Department of Education (Science and Engineering Education For The 1980s and Beyond, October 1980) describes many of the serious challenges we face in upgrading the quality of science and engineering work throughout our education system, from the elementary and secondary levels to advanced graduate work. We must now not retreat from the struggle against the growing scientific illiteracy of our people.

The research and training capacities of the major research universities are threatened by a growing shortage of advanced graduate students and young researchers in many fields of engineering (e.g., computer sciences, electrical engineering) and the physical sciences. Industry, in turn, is experiencing severe shortages of trained researchers, and so is turning to the universities for them. As researchers leave academic careers we are in danger of "eating our seed corn" in these disciplines. The Foundation should be the lead agency in designing a comprehensive strategy to modernize our instructional programs in the sciences. Rather than terminate the NSF competitive doctoral fellowship program, once the premier national science fellowship and an important symbol of federal leadership and commitment to excellence, we should restore the program to a position of prominence and respect.

Research and education do go hand in hand. To sever the links between them in this manner would be short sighted, counterproductive and very costly to us in the longer term. We should not seize the occasion of a near term budgetary and economic crisis to so radically restructure the Foundation. Rather than eliminate this responsibility, we believe the Congress should carefully reaffirm its importance and strengthen the bond between the Foundation's basic research programs and the Science Education Directorate. We strongly urge that this proposal be rejected. The necessary steps should be taken to insure that a strong, balanced and vigorous science education program is retained as a central function of the Foundation.

Instrumentation and Equipment: The Tools of Basic Science Are Wearing Out

The research and training capacities of the major research universities also are being steadily and increasingly hampered by rapidly obsolescent research facilities and instrumentation.

In June 1980 the Association of American Universities presented a report to the National Science Foundation: "The Scientific Instrumentation Needs of Research Universities." Copies have been provided to the Committee, the Executive summary is attached to. (The March 6 Science includes a summary of the report.) The study was carried out under the guidance of an advisory committee comprised of individuals from industry and other private institutions. The project team visited with several hundred research scientists and administrators in sixteen universities and in a number of government and commercial laboratories.

When the instrumentation available in university laboratories was compared with that in some of our best commercial laboratories, it was found that the median age of university instruments is twice that of our most advanced commercial laboratories. The serious consequences of this both for the quality of research that can be conducted in the universities now and for the adequacy of the training that can be accomplished on our leading campuses are obvious.

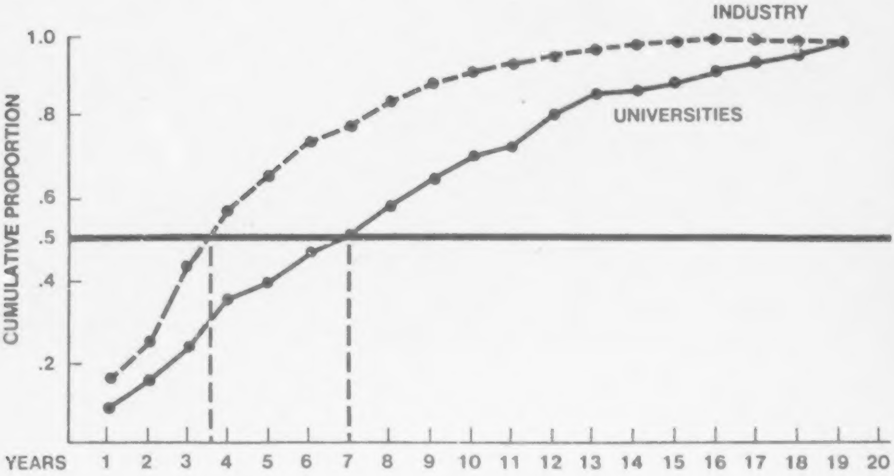


FIGURE 3. *Age of Instrumentation in Universities Twice That In Industry (Proportion of Instrumentation Inventory Purchased Less Than n Years Ago)*.

Source: L. Berlowitz, R. Zdanis, J. Crowley, J. Vaughn. *The Scientific Instrumentation Needs of Research Universities*, *The Association of American Universities*, June, 1980.

Problems were found across all institutions in five departments (physics, chemistry, biological sciences, earth sciences and electrical engineering) in the acquisition, use and maintenance of research instrumentation. While the configuration of these difficulties varies widely and reflects the great diversity among the institutions, the capabilities of institutions and departments to meet these difficulties vary also.

Leading researchers face great difficulty in replacing worn out and obsolete instrumentation and in acquiring new instruments needed to sustain work at the frontier of their fields. In the leading research universities scientists simply have not kept pace in meeting research instrumentation needs. Those heavily dependent upon federal project funds have seen their grant size fall way behind escalating research requirements. As a result many of the nation's pre-eminent researchers now work with inadequate tools and find that the pace of their research is hampered significantly. They often are forced to abandon preferred lines of inquiry. Increasingly strained operations and maintenance budgets cause research productivity to be compromised and the quality of education provided to advanced graduate students suffers.

New faculty seeking to initiate fresh research programs must do so in the face of escalating start-up costs. Routine support equipment needed to test, calibrate and augment primary research instruments often is especially difficult to find. In field after field the nation's leading academic research laboratories are falling behind to the point where scientific leadership and the development of new ideas and new lines of inquiry are shifting from universities to industrial laboratories and foreign competitors. Evidence of our declining ability to compete with Western European, in some cases Eastern European, and Japanese laboratories has grown to a convincing level. There now seems little doubt that in key fields the United States is waging a losing battle in an increasingly competitive world.

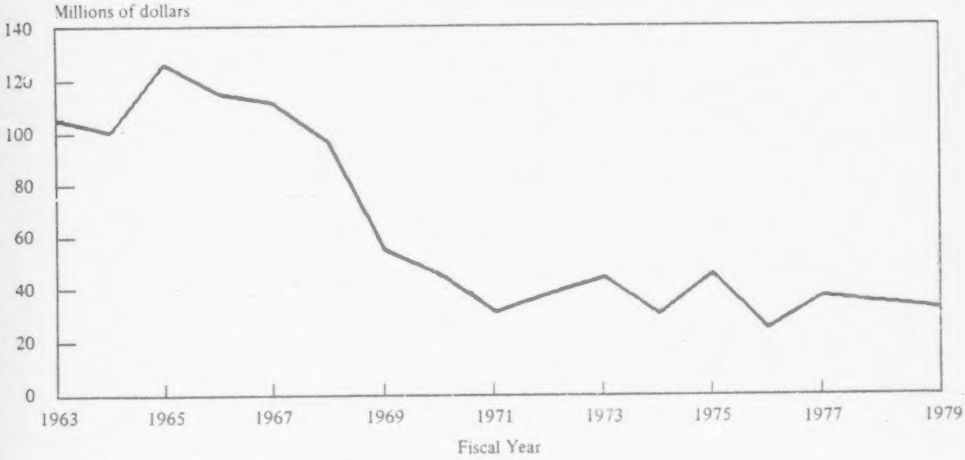
The effect of the declining competitiveness of our academic laboratories also is being felt by American industry. The development of new products and processes is being compromised by the lack of highly trained people. New scientists and engineers who join industry now often require additional training because they have not had hands-on experience with the state-of-the-art instrumentation and facilities. The pace of industrial innovation and invention thereby is slowed, further hampering our productivity and our ability to meet stiffening foreign competition.

In response to the AAU report and others the previous Administration proposed to begin now to take steps designed to reverse the long-term decline in federal investment for research facilities. They proposed to begin a major effort to upgrade the quality of university research and instructional laboratories. President Carter's budget for FY 1982 proposed to establish in the National Science Foundation an instrumentation and laboratory rehabilitation program at a level of $75 million, plus a $25 million initiative to start a major upgrading of engineering instructional laboratories. We regret to hear that these funds have been eliminated by the new Administration.

Research Facilities Are Obsolete

For about 15 years as shown on the following chart, the level of federal investment in research facilities in universities and colleges has steadily declined, from about

Federal obligations to universities and colleges for R&D plant



SOURCE: National Science Foundation

$126 million in 1965 to only $32 million in 1979. Now only the National Science Foundation, the Department of Energy and the National Institutes of Health provide any funds, and most of these are targeted on the development of major national user facilities intended to serve a large and diverse population of users. For many years almost no funding has been provided to upgrade departmental research facilities. State and private resources have been inadequate to fill the vacuum left by the withdrawal of federal suppport.

A survey of the research facilities needs of unversities now is being completed by the Association of American Universities. The University of Florida is participating in that effort. The completed survey is expected shortly, and it will be made available to the Committee. As a preview of that report I would share with the Committee the preliminary findings for the University of Florida.

As you will see from the table in the last three years the University of Florida has spent over $2 million for major facility modernization, repair, new construction and high cost research equipment. This year about $3 million is budgeted. Still we have fallen steadily behind in our ability to meet backlogged needs, and the backlog now is substantial.

Looking ahead just three years we estimate that the combined facilities needs of the university in five fields (biological sciences, chemical sciences, earth sciences, engineering and physics) and the medical school approaches

EXPENDITURES FOR RESEARCH FACILITIES
AND ESTIMATED NEEDS*
UNIVERSITY OF FLORIDA

FIELD	NEW CONSTRUCTION (a)			FACILITY MODERNIZATION (b)			MAJOR RENOVATION AND REPAIR(c)			SPECIAL PURPOSE(d) RESEARCH EQUIPMENT			TOTAL EXPENDITURES BY FIELD		ESTIMATED NEEDS NEXT 3 YEARS BY FIELD (e)
	Last 3 years	This year	Estimated needs next 3 years	Last 3 years	This year	Estimated needs next 3 years	Last 3 years	This year	Estimated needs next 3 years	Last 3 years	This year	Estimated Needs next 3 years	Last 3 years	Planned for this year	
BIOLOGY	n/a	n/a	13,000	2	36.5	152	201	18.6	125	n/a	n/a	150	203	55.1	13,427
CHEMISTRY	0	0	6,250	42	180	0	40	74	2,000	247	500	1,145	329	754	9,395
EARTH SCIENCES	0	n/a	n/a	0	9	64	0	125	20	0	660	n/a	0	794	84
ENGINEERING	0	25	15,000	65.6	115	3,000	0	0	0	3,390	650	5,204	1,375	790	23,204
PHYSICS	0	0	n/a	37	0	n/a	0	0	n/a	0	0	n/a	37	0	n/a
MEDICAL SCHOOL	0	0	22,500	212.6	0	980	0	268	0	0	0	552.5	212	268	24,035.5
	0	25	56,750	359.1	340.5	4,196	241	485.6	2,145	3,637	1,810	7,051.5	2,156	2,661	70,142.5

*thousands

Part of a survey, in progress, of six fields in sixteen universities by the Association of American Universities

Footnotes

(a) "new construction" means new buildings and new wings added to existing buildings. Major general purpose fixed equipment, i.e., equipment costing $5,000 or more and having a useful life of at least two years, is included; furniture and research instrumentation and equipment are excluded. Items such as cold rooms, ventilation hoods, and benches, are included, libraries are excluded; computer facilities are included. Expenditures for shared facilities are apportioned by discipline. Expenditures for construction planning are included.

(b) "facility modernization" means upgrading necessary to conduct a new generation of science; NOT routine maintenance or operations. Major general purpose fixed equipment as defined under (a) is included.

(c) "major renovation/repair" means substantial maintenance and repair (e.g., roofing, wiring); routine or light maintenance (e.g., painting) is excluded. Major general purpose fixed equipment as defined under (a) is included.

(d) "special purpose research equipment" means major research equipment capitalized at $100,000 or more.

(e) Includes projects for which the university has not secured funding but needs to accomplish to enable faculty who will be in place over these three years to conduct their research.

$70 million. This is our estimate of the investment that will be required if we are to prevent the further erosion of our facilities base. It is the investment needed just to enable the university to maintain present levels of scientific research and training. As large as the estimate seems it represents neither major expansions of present programs nor the initiation of major new program thrusts. These are facilities needed to enable faculty who will be in place to conduct competitive research. It is a backlog of unmet needs that has been accumulating steadily in the years since the federal investment in academic facilities on campuses was terminated.

Fifteen years of neglect have left their mark. The quality and pace of our research enterprise is being eroded. The capacity of many of our leading researchers to compensate with cleverness for what they lack is modern research tools and laboratories is now stretched to the extreme. The quality of our graduate education programs in the sciences and engineering is suffering as leading departments find it increasingly difficult or impossible to provide state-of-the-art training for advanced graduate students. As lines of inquiry are foreclosed, faculty often now scale their ideas to fit the limited capacities of worn facilities and their diminished expectations of receiving support to acquire the facilities and equipment necessary to do frontier research.

In summary, the very university laboratories that should be the plentiful sources of new ideas and processes, that should stimulate and lead industrial development and innovation instead find they are falling farther behind commercial laboratories and foreign competitors in their ability to do modern research. Although we remain ahead, or at least competitive, in many areas, the evidence that our resource base has eroded dangerously is clear and persuasive. As a nation we must face now the serious consequences of more than a decade of neglect. We can ill afford to ignore the problem any longer.

The seriousness and scale of the facilities problem require a fresh approach at the highest levels of government. To begin, we urge the Congress to restore to NSF the funding proposed by the former administration and to begin now a sustained effort toward the rehabilitation of academic research and instructional laboratories.

In addition, we suggest that the Federal government undertake a comprehensive government-wide assessment of the nation's research facilities needs, particularly university laboratories and major user facilities. Incentives to encourage greater industrial support for university research facilities and instrumentation are needed as well as strengthed national leadership to encourage the states to participate in a national effort to rehabilitate our basic science plant. The problem is large and serious. It requires the combined attention of government, industry and the universities.

Conclusion

Thank you Mr. Chairman for the opportunity to present these views to the Committee. I will be pleased to respond to your questions.

THE SCIENTIFIC INSTRUMENTATION NEEDS
OF
RESEARCH UNIVERSITIES

A Report to the National Science Foundation
by the
Association of American Universities

June 1980

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The Scientific Instrumentation Needs of Research Universities

EXECUTIVE SUMMARY

OBJECTIVES OF THE STUDY

- assess the current status of scientific instrumentation in major research universities
- identify factors which facilitate or impede its development, acquisition, use, and maintenance
- estimate the future consequences of present funding policies
- recommend appropriate policy changes

METHODOLOGY

- sixteen universities, six national and government laboratories, and nine commercial laboratories were visited; about 80 department heads and over 250 researchers and research administrators were interviewed in the universities; in addition, the views of approximately 60 researchers and research managers were gathered in visits to national, government, and commercial laboratories
- five fields of science and engineering were studied: physics, chemistry, biological sciences, earth sciences, and electrical engineering
- numerical data on instrumentation acquisition, age, and replacement were gathered from 14 universities and four commercial laboratories

THE PROBLEM

Instrumentation is essential for progress in experimental research. Scientific knowledge has advanced rapidly; new instruments, more costly but qualitatively superior to earlier ones, have allowed measurements previously impossible. The rate of change has been great, competition among researchers intense. The capacity of university researchers to work at the frontiers of knowledge has important consequences for the nation's future research productivity and for the training of future generations of scientists and engineers.

The federal government has adopted a variety of funding policies for the support of research instrumentation: the competitive project system, special instrumentation programs, formula grant programs, block-funded centers, federally sponsored research centers, and regional instrumentation centers chief among them. For about 15 years, federal support for basic research has gradually declined; now support levels are further strained by rapid inflation. But inflationary price increases are simply the rising baseline upon which are superimposed the frequently much larger increases resulting from instrumentation advances.

ASSESSMENT

The great diversity of instrumentation needs found among institutions visited precludes simple generalizations. However, problems in the acquisition, use, and maintenance of research instrumentation were found in all of the leading universities visited. The precise configuration of these needs and problems varies widely. The capabilities of institutions and departments to meet them do also.

University researchers face great difficulty in replacing worn-out or obsolete instrumentation and in acquiring new instruments needed for frontier research. A comparison of university instrumentation inventories with those of two leading commercial laboratories reveals that the median age of university equipment is *twice* that of the commercial laboratories' instrumentation. Even the nation's major research universities have not kept pace in meeting instrumentation needs. Researchers heavily dependent upon federal funds have witnessed grant size fall behind escalating research requirements. As a result, many work with inadequate tools that impair the pace of research, force closure of lines of inquiry, strain operations and maintenance budgets, and compromise the advanced education of graduate students.

Start-up funds for new faculty often are shrinking as costs rise. Support equipment is needed to test, calibrate, and augment primary instruments. Often it is especially difficult to fund. Funding for operation and maintenance costs is increasingly difficult to obtain. As a result, faculty and students sacrifice research time to these routine tasks.

Many research facilities are in need of renovation or replacement; federal funding for these purposes has decreased, however, and universities lack the funds to respond. Signs that aging facilities now impede research were found in many laboratories and support facilities.

Local university needs vary widely, reflecting the unique circumstances under which each institution operates and the great diversity between and even within the five fields studied. Present funding policies do not provide sufficient flexibility to deal with such local circumstances.

When compared with government and commercial laboratories visited, most university laboratories fare poorly. The best-equipped industrial laboratories surpass almost all university laboratories visited. One university researcher captured the sense of disparity and observed, "the ivory towers are now in industry." The director of one leading industrial research laboratory described the struggle of university researchers as he has observed them as "pathetic." When asked to contrast their laboratories with foreign laboratories, a number of university researchers stated that many, most notably those in Japan and West Germany, are now superior.

CONCLUSION

The quality of research instrumentation in major university laboratories has seriously eroded. Not all, but many researchers in the nation's best-funded universities are struggling to work effectively with obsolete tools. The equipment being used in the top-ranked universities has a median age twice that of the instrumentation available to leading industrial research laboratories.

Three *causes* are identified:

- a relative decrease in instrumentation support
- inflexibility within the project system
- insufficient support for maintenance

Three major *consequences* are:

- diminished research productivity
- reduced training capacity
- decline in international competitive status

RECOMMENDATIONS

Federal policy for the support of research instrumentation should provide for a basic three-part funding strategy:

- strengthen instrumentation funding in the project system
- expand special instrumentation programs
- create in the National Science Foundation a new, supplemental formula grant program to provide needed flexibility to meet diverse institutional needs

FUTURE STUDIES

Five studies are recommended: 1) a thorough analysis of foreign research funding policies and programs and their implications for the competitive stature of American science should be undertaken; 2) a study of cooperative research arrangements between industries and universities and the factors—including federal policies—that encourage and discourage them is needed; 3) the planned assessment of regional instrumentation centers should include consideration of the concerns documented in this report; 4) universities should assess current instrumentation policies and develop mechanisms and incentives designed to promote effective sharing of instrumentation; 5) an assessment of the costs and benefits of federally-mandated equipment inventory and reporting systems should be undertaken.

Mr. Walgren. Thank you very much, Dr. Marston.

The chairman of the full committee, Congressman Fuqua, had wanted to be here.

Dr. Marston. I will have lunch with him in a few minutes.

Mr. Walgren. That is great.

Dr. Roaden.

[A biographical sketch of Dr. Roaden appears in his prepared statement, p. 471.]

STATEMENT OF DR. ARLISS ROADEN, PRESIDENT, TENNESSEE TECHNICAL UNIVERSITY, TESTIFYING FOR AMERICAN ASSOCIATION OF STATE COLLEGES AND UNIVERSITIES

Dr. Roaden. Mr. Chairman, thank you for the opportunity of appearing before this subcommittee. I am Arliss Roaden, president of Tennessee Technological University, and I represent the 341 members of the American Association of State Colleges & Universities. These are State colleges and universities in States throughout the country. I also represent the American Council on Education in my statements.

The member institutions of the American Association of State Colleges and Universities educate 2½ million students, about 1 out of 4 of all baccalaureates awarded, and they have 106 schools of engineering and award approximately one-fourth of the baccalaureate degrees in engineering. My colleagues from the large research universities and from the private universities approach this matter from a somewhat different perspective, but we all arrive with mutual concerns, and that is that the American system of science and technology is in deep trouble and we urgently request some immediate attention.

This committee, Mr. Chairman, has been quite sympathetic in the past to the needs of science education, and I implore you, we just must not accept the administration's plan virtually to eliminate the Science and Engineering Education Directorate. The eighties, perhaps more than any era in our history, will demand far more of our scientists and engineers. The demand already far exceeds our capacity to produce young scientists and engineers.

Reference has been made this morning to a paper released by the Association Council for Policy Analysis and Research, "The National Investment in Higher Education." That council concludes like virtually every other policy council that has looked at this matter, that higher education educates our citizens, enriches our communities, conducts much of our most important research. The fulfillment of its mission is indispensable to America's well-being and justifies a major national investment. Yet today the President is proposing virtual elimination of Federal support for science and engineering education.

Realistically, there is no other source of support to keep these programs alive: not the States, where budgets are in jeopardy, not the institutions, and not industry. Only about 1 percent of the industrial profits from the marketplace now finds its way into the support of preparation of scientists and engineers. Since the alarm of Sputnik prompted Federal support of science education and engineering education to a new high, from about $60 million in 1960 to $130 million in 1968, support has been declining. In 1970, 27 percent of the National Science Foundation budget was in the science and engineering education directorate. In 1981 it was 7½ percent.

Please know, Mr. Chairman, as president of a university I am all too familiar with the ravages of inflation, rising costs, and diminishing support. The economic recovery of our Nation must be the goal of all Americans. Priorities have to be set and sacrifices made. But I am convinced that it is shortsighted, indeed irresponsible to sever the primary source of a healthy, productive economy, that is scientific and technological knowledge and expert manpower. It is sad but true that in science and mathematics we are falling behind other industrialized nations, the Soviet Union, Japan, West Germany, and France. It is time for a renewed commitment to excellence.

This bad news was delineated in a recently published report commissioned by President Carter by the Department of Education and the National Science Foundation entitled "Science and Engineering Education for the 1980's and Beyond." As a result of that report, President Carter recommended a 38.7-percent increase up to $111.9 million for science education. President Reagan and the current administration, as I have indicated, have incredibly recommended the virtual abolishment of the directorate.

Mr. Chairman, this problem transcends partisan politics and touches the heart of America's future scientific and technological position.

I should like now just briefly to share some examples of what programs sponsored through the Science and Engineering Education Directorate have meant to my institution and to other State colleges and universities. First, the local course improvement program, we call it LOCI, which has as its objective to encourage colleges and universities to introduce new scientific and educational concepts to undergraduates and to enhance the quality of teaching. In 1980 there were 125 LOCI grants, 27 to AASCU institutions, one to Tennessee Tech in the amount of approximately $25,000, which was supplemented by another $15,000 from the institution. Its purpose was to improve undergraduate courses in engineering mechanics and materials science. We developed an instructional computer-graphics program to aid students in understanding difficult topics, such as stress-strain curves and volume fraction analysis.

The second set of programs we call the ISEP program, the instructional scientific equipment program, intended to provide up-to-date equipment and educational technology. In 1980 there were 215 awards, 37 to AASCU institutions; Tennessee Tech received one in electrical engineering for $20,000; another $20,000 was provided by the institution to develop thin-film microelectronics laboratories. This is for the fundamental study of electrical properties of materials. In the mechanical engineering department we upgraded the control and simulation laboratories. These laboratories are required of all mechanical engineering undergraduates today.

A third program, comprehensive assistance to undergraduate science education. In 1980 there were 72 grants, 11 to AASCU institutions. Tennessee Tech received a grant of $144,000 supplemented by institutional resources of $74,000 in undergraduate interdisciplinary real-time digital system program development that involved six engineering departments and in arts and sciences, the departments of biology, geology, chemistry, and computer sciences. This permitted the development of four stand-alone microcomputer centers at one-tenth of the cost of standard systems.

Mr. Chairman, I honestly don't know how our institutions could meet the needs of a technological society without the benefits of such programs as those of LOCI, ISEP, and CAUSE, which in 1980 provided some $3 million to our member universities.

We are also heavily involved in the continuing education of primary, middle school, and highschool teachers and the improvement of their teaching of youngsters at those grade levels.

We are also concerned with our engineering programs. In the last 6 years the engineering enrollment of Tennessee Tech doubled. All of our institutions across the country will produce approximately 60,000 engineers this year. One company recently recruiting on my campus expects to hire more than 3,000 engineers alone. We can't come close to meeting the current demands.

The faculty salaries in engineering are not competitive and the source of faculty members is declining. Baccalaureate graduates are not enrolling in graduate school and there is now a decline in graduate-school enrollment in engineers. And indeed, the salaries of our baccalaureate graduates from industry exceed what we are able to pay new Ph. D. graduates who join our faculty.

In summary, I described the insatiable needs of our society, Mr. Chairman—needs for scientific and technological knowledge and expert manpower. These are needs which I believe must be met if we are to achieve the objectives, those enunciated by President Reagan, the Congress, and all of us, that is, a secure Nation, a healthy, productive economy. We are now behind other industrialized countries in science, mathematics, engineering education, and I hope you agree, members of the subcommittee, that we must not, we cannot with one stroke of the pen obliterate the National Science Foundation programs in science and engineering education.

Thank you.

[The prepared statement of Dr. Roaden follows:]

Statement by

Dr. Arliss L. Roaden

President

Tennessee Technological University

on

The Fiscal Year 1982 National Science Foundation

Budget Authorizations

on Behalf of

American Association of State Colleges and Universities

and

American Council on Education

Before the

Subcommittee on Science, Research and Technology

Committee on Science and Technology

U. S. House of Representatives

Rayburn House Office Building

March 10, 1981

My name is Arliss Roaden and I am President of Tennessee Technological University in Cookeville, Tennessee, a position I have held for the last 7 years. Prior to assuming the Presidency at Tennessee Tech I was at Ohio State. During my 12 years at Ohio State I served as an Assistant Professor, Associate Professor and Professor of Education, as a Vice Provost for Graduate Affairs and Dean of the Graduate School and Vice Provost for Research. I received my B. A. degree at Carson Newman College and My Ed. D. at the University of Tennessee in Educational Administrations with related fields of sociology and higher education. I am a member of the American Association for the Advancement of Science, American Academy of Political and Social Science and American Educational Research Association.

I am pleased to have the opportunity to appear before this subcommittee today to testify on the FY 1982 National Science Foundation Authorization bill with particular emphasis on the Science and Engineering Education Directorate.

I represent the 341 member institutions of the American Association of State Colleges and Universities, and am currently chairman of its Committee on Science and Technology. I also am speaking for the American Council on Education.

Our institutions are located throughout the United States and include the following colleges and universities which will be familiar to the members of the subcommittee: 17 of the Pennsylvania state colleges, 18 of the California state colleges, 8 of the Ohio state colleges, SUNY at Fredonia, North Texas State University, Cameron University, University of Science and Arts of Oklahoma, Bridgewater State College, St. Cloud State College, Keene State State, Plymouth State, Eastern New Mexico, Western New Mexico, and nine of the New Jersey state colleges.

With a combined enrollment of 2½ million students, the 341 state colleges and universities of AASCU enroll one out of 4 of all baccalaureate degree students in the country. Our institutions play a major role in our nation's science effort. Many students who ultimately pursue advanced degrees in scientific and technical fields receive their basic undergraduate training at our institutions. A large portion of the nation's future elementary and secondary school science and mathematic teachers are educated at AASCU colleges and universities. These teachers must be able to communicate the knowledge and skills that will enable our youth to live in an increasingly complex scientific and technical society.

In engineering AASCU's 106 Schools of Engineering award close to 25% of the B. S. degrees in engineering annually. Our involvement in engineering is growing and, in 1978, one of our members, the University of Northern Iowa, became the first institution to offer a doctoral program in industrial technology.

Mr. Chairman, it gives me great pleasure to appear before you today in the company of my distinguished colleagues from the research universities and from the private undergraduate colleges.

Though we approach the problem from differing perspectives, we are all concerned with the adequacy of science and engineering education in the U. S. today. The American system of science and engineering education is in a state of crisis which warrants immediate attention and appropriate action.

We cannot and will not accept the Reagan Administration's plan to virtually eliminate the Science and Engineering Directorate at NSF. Accordingly, the following telegram was sent on March 3 to President Reagan and OMB Director David Stockman:

> The 341 member institutions of the American Association of State Colleges and Universities protest the plan to drastically cut the programs of the Science Education Directorate at the National Science Foundation. These programs are of vital importance in the training of America's future engineers and scientists. Such cuts will ultimately jeopardize our nation's security and economic well being by undermining U. S. technological and scientific foundations. Signed, Allan W. Ostar, President, AASCU.

In the past this subcommittee has listened sympathetically to the problems faced by our colleges and universities and has consistently recommended funding for the Science Education Directorate at levels which would help our institutions meet the challenges ahead. We hope that under its new leadership this subcommittee will continue in its role of support and that the appropriations committees will adhere to the guidelines set here.

I wish to cover several main points in my testimony today:

- -- Our institutions of higher education are a national resource,
- -- Federal support of science and engineering education is an investment in America's future scientific and technological strength,
- -- This Federal support has been steadily declining, and now faces virtual elimination, and
- -- Current budgetary decisions must be weighed against their future impact on the American economy, society and nation as a whole.

I would like to tell this Committee some of the ways in which National Science Foundation funding has benefited my institution, Tennessee Technological University, and some of the other AASCU members.

The National Investment in Higher Education: 1981, a recently released paper by the Association Council for Policy Analysis and Research, stated that "Higher education is one of America's greatest national resources. It educates our citizens, enriches our communities, conducts much of our most important research and contributes countless other benefits. Fulfillment of its mission is indispensable to America's well-being and justifies a major national investment."

A byproduct of this educational process is the scientific knowledge vital to our country's well being. In releasing the FY 1982 NSF budget, Dr. John B. Slaughter, its director, said, "Success in achieving virtually all our national goals for the 1980's -- more vigorous economic growth, a stronger competitive position in world markets, enhanced national security, better health and quality of life for all people -- will depend in part on new knowledge which can come only from scientific and engineering research."

The American system of higher education couples the production of new knowledge with the training of skilled manpower at its universities and colleges. There is a highly complementary relationship between the performance of basic research and the education of future scientists and engineers. If we as a nation do not adequately support the training of our scientists and engineers, then our technological base will erode and our store of scientific knowledge will diminish.

In the past support for our research and training has been multi-faceted and dependent upon Federal, state, private and institutional sources. This mix meant that no one sector could dominate or dictate the teaching or the research occurring at our colleges and universities.

Yet, today President Reagan is proposing the virtual elimination of Federal support for science and engineering education. How will these programs continue? The states already experiencing budgetary deficits and taxpayer revolts will not be able to fill the gap. Institutional resources are already strained to the limit. Nor will it be desirable to have industry as the sole source of support. Do we want industry to dictate what kind of scientists and engineers our institutions produce and what kind of research is performed on the basis of profitability? Should the competitive pressure of the marketplace determine research and training decisions? I think not.

The Federal role in science and engineering education, though limited, is a crucial one. Though the nature and extent of this support for science and engineering education has changed in response to national needs -- for example, the public alarm resulting from Sputnik saw a surge in funding -- it has been an integral part of U. S. science and technology policy for the last 35 years.

Despite the fact that the Federal role in the support of science and engineering education is a vital one; despite the fact that science and engineering education is the basis for future research discoveries and technological achievements; despite the fact that the maintenance of the American scientific and technological base is of national significance to our productivity, national security and general well being as a nation -- despite all these compelling reasons -- Federal support for science education has been declining and now plunging to ever lower levels of support.

In dollar support Science Education at the National Science Foundation rose from $60 million in 1960 to a peak of $130 million in 1968 and then began to fall steadily to its current level.

In 1970 funds for science education amounted to 27% of NSF's total budget, but for 1981 the science education's share was down to 7.5%.

Science Education has always been the first program to be cut at NSF. In Fiscal Year 1981 cuts in Carter's revised budget for science education were disportionately higher and OMB, in making its final determinations, further reduced funding for Science Education Directorate, while preserving other Directorates.

William D. Carey writing in Science 1/23/81 observes that "Science education continues its decade-long record as NSF's habitual loser," in the budgetary process.

Though my request to you today is to insure the future of Science Education at NSF, I think I would be remiss to ignore the grave economic situation in our country today. As a college president I am all too familiar with the problems caused by inflation, rising costs and diminishing support. The economic recovery of our nation must be the goal for all Americans. But to cut funds for science and engineering education seems short sighted and, even, irresponsible. The investment that the Federal government makes in science and engineering education today -- minimal by comparison to many other programs -- will have a long-term return to society.

Former NSF Director Richard C. Atkinson wrote in The Chronicle of Higher Education (3/2/81), "Many of the economic-policy choices we make today will shape our society for years to come. It is clear that the long-term well-being of this country continues to be tied, through science and technology, to the innovativeness and productivity that have traditionally characterized the U. S. economy." We must insure our long-term well-being through support of programs that foster research and train scientific manpower.

In examining budget proposals for the elimination of Science Education within the National Science Foundation, it is important for all of us — the authorization committees, the appropriations committees, the Foundation, OMB, the President — to take into account the findings of a recently published report, Science and Engineering Education for the 1980's and Beyond. This report stemmed from President Carter's request to the Department of Education and the National Science Foundation for an assessment of the long term adequacy of U. S. science and engineering education.

The report's findings indicate that there is a need to improve the quality and amount of science, mathematics and engineering education provided to U. S. students. Our schools and colleges are falling behind the Soviet Union, Japan, West Germany, and France in science and mathematics education. The level of scientific literacy in the U. S. is lower than in other industrialized countries.

The report recommended "a new national commitment to excellence in science and technology for all Americans." A coordinated program to "increase public awareness of the need for excellence in science and technology and help the schools fulfill their role in formal science and technology education" is called for.

President Carter heeded this advice when he proposed an increase of $31.2 million, or 38.7%, to $111.9 million in the FY 1982 funding for Science and Engineering Education.

The Carter budget proposals for Science and Engineering Education were a constructive response to the findings of that report. The nationwide shortage of training facilities in engineering and computer science departments was to be alleviated through a new $25 million program for up-to-date instructional equipment and for departments of engineering and computer sciences. In addition, $3 million was requested to establish a program of traineeships in these areas to increase graduate enrollment and help alleviate severe faculty shortages in the long run.

Two months later President Reagan seems to feel that the bad news in this report can be ignored. Mr. Chairman, I find this shocking. The data in this report and its implications transcend partisan politics and touch at the heart of America's future scientific and technological position. Are the findings and the suggested recommendations any less relevant today than they were when President Carter ordered the assessment? I think not.

As this subcommittee considers authorizations of Science Education I would give yo some idea of what these programs have meant to my institution. I would also like to share with this committee some examples of Science Education programs operative at other AASCU institutions.

The Local Course Improvement (LOCI), Instructional Scientific Equipment Program (ISEP) and Comprehensive Assistance to Undergraduate Science Education (CAUSE) programs within the Science Education Directorate have all been important to Tennessee Tech, as well as other AASCU institutions.

The objective of the LOCI program is to encourage colleges and universities to rapidly introduce important new scientific and educational concepts to undergraduates and to enhance the teaching capability of science faculty. A contribution from local or other sources of at least 50% is required. Institutions receiving the award are expected to continue offering the revised instructional activities at their own expense.

In FY 1980 out of 125 LOCI grants, AASCU institutions received 27 awards. Tennessee Tech received its first LOCI award that year. The project is funded at $24,997 from NSF and $14,908 from Tech. Its aim is to improve undergraduate courses in engineering mechanics and material science. The plan is to develop instructional computer graphics programs which will supplement lecture presentations. The program will be tutorial in nature and will allow for active interaction of the students. It is anticipated that computer graphics will aid the students in better understanding of difficult topics such as stress-strain curves, volume-fraction analysis, and truss and frame analysis. An evaluation of the computer-graphics method of instruction with the normal teaching methods will also be made.

The Instructional Scientific Equipment Program (ISEP) is a major program of support for our institutions. ISEP awards classroom laboratory and field work experiences for undergraudate students by providing funds for up-to-date equipment and educational technology. In FY 1980 AASCU institutions received 37 of the 215 awards made in this program.

Much will be said today about the problems of outdated equipment and the inability of colleges and universities to replace obsolete equipment. This is no less of a problem for our institutions than it is for the research universities. The ISEP program has meant a great deal to Tennessee Tech. Since each institution is required to provide at least half the cost of equipment, our purchases have been acquired sooner than if we proceeded with the usual budgetary channels.

For example, in the Electircal Engineering Department we were awarded $20,000 (to be matched by $20,000) from Tennessee Tech to develop a thick film microelectronics laboratory. This laboratory has now been expanded using university resources to include thick film facilities. Although the lab initially served undergraduate students, it now serves both undergraduate and graduate students for the fundamental study of electrical properties of materials.

Our Mechanical Engineering Department was able to equip a much needed Transport Phenomena Laboratory and totally upgrade both the Control and Simulation Laboratories. The Transport Laboratory serves undergraduate students by allowing experimentation in fluid mechanics, mass transport, and heat transfer. This lab supports three lecture courses. Both the Control and Simulation Laboratories are required for all mechanical engineering students. Students can perform experiments in analog computation, digital computation, pneumatic and hydraulic controls, and motor speed and displacement controls. These two laboratories support four lecture courses.

At Humboldt State University (CA) a 1980 ISEP award permitted the acquisition of a scanning electron microscope for joint use in the biology and geology departments. This microscope will allow students to study such diverse subjects as blood cell structure, plant pollens and microfossils.

NSF in FY 1980 funded three special projects in a new program initiative aimed at developing ways of extending the use of existing instructional scientific equipment. Two of these awards went to AASCU institutions. The University of Missouri at St. Louis received funds to renovate a T-60 Nuclear Magnetic Resonance Spectrometer. Refurbishing the equipment will be completed at 1/3 the cost of replacement and will result in improving the quality and scope of the chemistry curriculum from sophomore to senior year. At SUNY New Paltz funds will be used to update equipment for microscopic studies and analyses of dispersion; this will significantly benefit undergraduate instruction in the Department of Biology.

The Comprehensive Assistance to Undergraduate Science Education (CAUSE) is another program of vital importance to our AASCU institutions. In FY 1980 NSF awarded 72 grants; 11 went to AASCU institutions.

Tennessee Tech was fortunate to secure a CAUSE grant of $144,238 that year. In addition to the NSF funds, the University provided $73,929 for a total of $218,167 to be used in the development of an undergraduate interdisciplinary real-time digital system program. This is a three year interdisciplinary project involving six engineering departments and four non-engineering departments -- biology, earth sciences, chemistry and computer sciences.

In the past undergraduate students at small universities such as Tennessee Tech have been unable to do real-time computer work due to the cost of standard computer equipment. This project has permitted the development and acquisition of four "stand-alone" microcomputer systems at about one-tenth of the cost of standard systems. The laboratory will permit undergraduate students to learn and apply data acquisition systems currently being used by large processing industries. Biology sutdents will learn techniques for acquiring environmental information through data acquisition systems designed and tested in the micro-computer laboratory.

Faculty from ten teaching areas are presently undergoing training in the lab so that they will be able to use and teach in the laboratory. For the first time this fall, Tennessee Tech offered an undergraduate course that will deal with the design and use of micro-computers in the processing industries.

Another CAUSE grant for the use of computers in undergraduate science education went to Lyndon State College (Vermont). The grant of $143,648 will support the college's efforts in the development of curriculum resources in computer sciences and encourage an increase in computer literacy among students. Computer assisted instruction (CAI) will take place in courses related to the College's science and meteorology programs permitting students to study theories and solve problems at a pace commensurate with their understanding of the material. The CAUSE grant was supplemented by $80,000 from the Digital Corporation.

These three programs -- LOCI, ISEP and CAUSE -- have been of major importance to AASCU institutions. In FY 1980 they provided $3 million in vitally needed funds to our campuses. The long term pay off when the generation of students currently enrolled at our colleges and universities become actively involved in our science effort and industrial base will be significant. Without these funds it is unlikely that we would have been able to move ahead as rapidly.

AASCU institutions are also involved in projects designed for the continuing education of primary, middle and senior high school teachers of mathematics and the sciences. The Pre-College Teacher Development Program at Northern Arizona University brought together local university scientists and teachers, administrators and tribal representatives from a number of reservations to determine their special science education needs. Proposals for science and math education that reflect their particular cultural settings were developed and are now being implemented in a number of schools with large Indian populations. Another grant under this program went to New Jersey Institute of Technology. Through laboratory and class work utilizing faculty from the Institute's chemistry, physics, mathematics and engineering departments, Secondary school teachers will be provided with an objective view of the complex and ever-changing energy problem. The goal is to carry energy and conservation information to the secondary school level.

Many of our LOCI, ISEP and CAUSE grants at Tennessee Tech have been oriented towards the improvement of our engineering programs.

At Tennessee Tech our engineering enrollment during the last thirteen years has just about doubled in size. Yet this tremendous increase in size has not been reflected in equal growth of faculty, resources or equipment. On the contrary our institution has had to deal with more students and less faculty.

A similar story can be told at California Polytechnic State University at San Luis Obispo where there has been a 31% increase in engineering enrollments over five years despite the fact that the university has a ceiling on enrollments by major. This 31% increase has taxed the university's resources to the point where they are no longer able to meet the demand for students wishing admission. For fall 1981 1,161 students who applied to the School of Engineering have been rejected because of faculty and facility restrictions.

The hiring of additional PhD faculty for our engineering school to cope with enrollment surges has been difficult for two reasons: the faculty salaries are not competitive and the available pool of potential faculty is too small. At the present B. S. graduates from engineering schools are getting annual salaries upon graduation which exceed academic salaries of new faculty with doctorate degrees. This discourages qualified students from pursuing graduate studies which eventually would lead to a faculty position. Nor are we able to retain the faculty that we have. Each year some are lured away by the higher salaries offered by industry.

The University of Alabama in Huntsville for the past several years has only been able to fill half the engineering faculty positions open; this year, they were only able to fill one position. In addition, the university lost to industry six faculty members this year.

The difficulty of acquiring and maintaining adequate faculty size coupled with surging enrollments has meant that many of our classes are double the size they were several years ago. I estimate that over two-thirds of our classes are now too large. This is particularly devastating in our design courses where individual and small group attention is a must -- where many solutions to design problems are possible and all have to be checked individually.

California Polytechnic State University at San Luis Obispo has found class size to be a leading contender in the decline of faculty morale and a contributor to faculty looking for employment opportunities elsewhere. Class size is excessive at all levels, due primarily to budgetary problems and lack of faculty. In the engineering programs there is a serious shortage in faculty which has resulted in the inability of the university to offer certain necessary courses at times when they are required. The possibility of some some students making normal progress in their degree programs is thus being jeopardized.

At the Montana College of Mineral Science and Technology record levels of enrollment coupled with problems of hiring and retaining faculty have resulted in class sizes large enough to threaten the school's accreditation.

Problems caused by faculty shortages and retention are further compounded by the poor state of our laboratories. The fact is that we have been unable to maintain our laboratory equipment. It is currently outdated and in a state of disrepair. We have not been able to replace the equipment that we need. Our students are being trained on equipment which is obsolete to industry. During the last ten years we have depended very heavily upon the ISEP, LOCI and CAUSE programs to help in the replacement of our obsolete equipment. For example, without the CAUSE program described above we would be at ground zero in microprocessors.

Because funding by the state of California has been cut back in the past few years California Polytechnic State University at San Luis Obispo has been unable to keep abreast of needs in laboratory equipment, maintenance and replacement. They lack technicians to maintain and repair equipment; there aren't enough funds to purchase repair parts and much of the equipment is so old it is difficult to obtain replacement parts. In some cases the University has asked for and received donations from industry. Industry's obsolete equipment is then used in the laboratory instruction programs -- though obsolete by industry standards this equipment is in most cases newer than the equipment we already have in our laboratories.

Thank you for giving me the opportunity to appear here today. I hope that my plea has been heard. I would be happy to answer any questions you may have.

Ir. **Walgren**. Thank you very much, Dr. Roaden. We appreciate t contribution.

)r. Powell?

A biographical sketch of Dr. Powell follows:]

Dr. James Lawrence Powell

r. James Lawrence Powell is Vice President and Provost of Oberlin College in ·rlin, Ohio. In addition to his administrative position, he holds academic rank as fessor of Geology and is a published researcher. A native of Berea, Kentucky, Dr. vell is a graduate of Berea College and received the Ph.D. from the Massachu-s Institute of Technology.

'ATEMENT OF DR. JAMES POWELL, VICE PRESIDENT AND PROVOST, OBERLIN COLLEGE, TESTIFYING FOR GREAT LAKES ASSOCIATION/INDEPENDENT COLLEGES

Dr. **Powell**. Thank you very much, Mr. Walgren. I, too, am ·ateful for the opportunity to appear before you, and coming last, find there is little that hasn't already been said, so I will try to ·iefly summarize my remarks and make sure that I am not any ıore redundant than is necessary.

This subcommittee, as Dr. Roaden and others have said, has layed a vital role over the past few years in trying to strengthen ıe Nation's effort in science and science education. Charles Iosher and, more recently, Donald Pease, both from my district in)hio, Representative Fuqua, Representative Brown, and others ıave repeatedly shown that they understand that a country with·ut a strong program of science education simply cannot win out in his age of emphasis on technology-based productivity increases—Ir. Pease has just come in.

Mr. **Walgren**. Yes; if you would suspend briefly.

Dr. **Powell**. Yes; I will be glad to defer to Mr. Pease.

Mr. **Walgren**. I wanted to say that Mr. Pease was going to try to ɔe here when you testified. I am glad that he made it.

Dr. **Powell**. Well, the science education community pretty clearly once again needs to call on this subcommittee for leadership and guidance. It appears you are our last hope. Those of us outside of Washington, scientists and members of the scientific community have been in a state of shock at the proposed closing down of the scientific education programs of the National Science Foundation. And this morning I have been further shocked and, at the risk of seeming impolite, might say even angered by hearing the statements of the top officials of the National Science Foundation and a representative of the National Science Board. I think Mr. Rutherford was right when he said that Mr. Orwell would have understood their remarks.

If science education does not have a friend in the top administration of the National Science Foundation and if we can't depend on the National Science Board, then we can only turn to you as our last hope, as I said. I would like to ask this subcommittee to ask the National Science Board to take up this question of science education, put it up to a vote at their next meeting—I gather they have one every month—and see if for the record they will come down for the abolition, the zeroing out of the science education programs. I think if they do, the rest of the scientific community in the country would like to be aware of that.

Let me also say a brief word again about the mandate that Congress gave to the Foundation. Apparently we can't repeat it often enough. The Foundation is to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences. It is to initiate and support programs to strengthen scientific research potential and science education programs at all levels. Every time research is mentioned, science education is mentioned. And I think it is just double speak to say that having no funds for science education does not represent some kind of a violation of that mandate. If you have no funds, you have no program, and then you are in violation of the mandate. I can't think of anything that is more clear than that.

It seems to me that the words that established the mandate of the Foundation were chosen with great care and that this subcommittee and the Congress ought to insist that they be reflected in the actions and budget of the Foundation.

I submit that the close connection between quality science education that occurs in one generation and quality basic research that occurs in a later generation and the explicit mandate for support of science education that I just quoted are of fundamental significance when one discusses the goals of the Foundation programs. This subcommittee has recognized many times before that there is a continuity in the process of science education and in the strategies for developing first-rate scientific talent, which makes nonsense out of any sharp demarcation between, for instance, the graduate level and the undergraduate level. It appears now, however, that the Foundation is ready to make such a demarcation absolutely total and final.

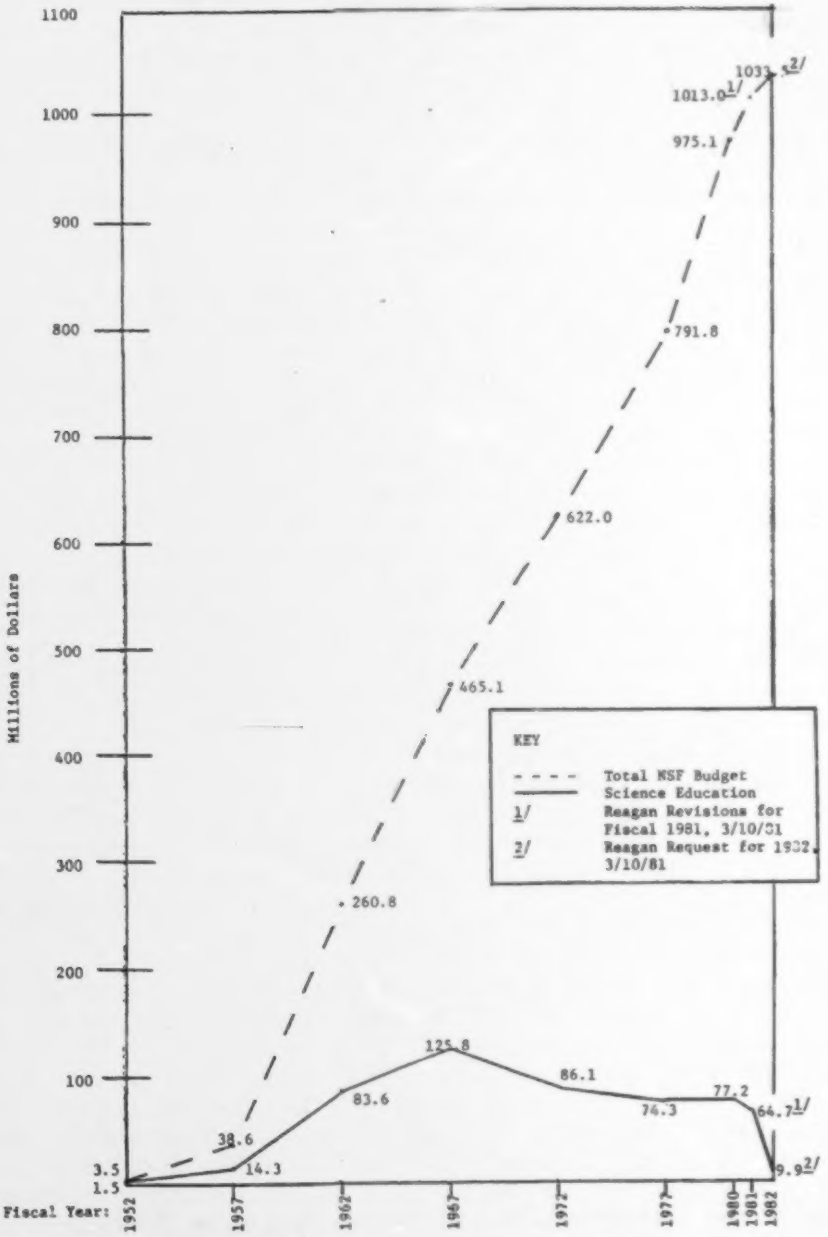
I would also like to take exception to Director Slaughter's statement that funding at the graduate level will achieve the goals of science education. It will accomplish them in a small segment. It will not help the grade schools; it will not help the high schools, community colleges, and undergraduate colleges. It will not do a thing for them. And one of the things I might add, something that also grates a little bit on us from the undergraduate colleges, is that we send large numbers of students to these graduate universities. I would like to hear an equal expression of concern from all of them at the closing off of the pipeline which will not then produce the graduate students they are going to be looking for in the next 3 and 4 years.

Dr. Roaden summarized the valuable programs that the Foundation has created, and I think due credit should be given to them, Dr. Rutherford and his predecessors, for doing a great deal with a quite insufficient amount of money. Dr. Roaden mentioned LOCI, and CAUSE, and so on. I don't want to repeat all those. But I would say that to claim that these programs have been funded at such a low level that they are not doing any good is just ridiculous. I would support Dr. Rutherford in saying that some money is better than no money at all. On my campus—and I come from a fairly well-off institution—these programs have been extremely valuable, and I think what they must be doing at colleges that are less well off may be even more valuable. We would rather have some amount of money than none at all. I just don't accept that argument; I don't think there is logic to it at all.

I would like to pass out a graph that will summarize the record of the Foundation in science education over the past—well, since the Foundation began, if I could just hand this out.

[The graph follows:]

Comparison of
NSF TOTAL BUDGETS AND NSF SCIENCE EDUCATION BUDGETS
Five-Year Intervals Fiscal Years 1952-1977 and 1980-1982
(Millions of Dollars)



Sources: "Total NSF Obligations and Obligations for Education in the Sciences FY 1952-1979," NSF: AD/SE, 1-12-78.
National Science Foundation Budget in Brief, Revised March 1981

Independent Colleges Office
March 24, 1981

Dr. Powell. Dr. Rutherford mentioned this fact, but I think this shows it pretty graphically. It shows the rise in total Foundation budget by the dashed line and the budget for science education by a solid line. I point out that these are in current dollars. If we had done this in constant dollars, the bottom line would have just sort of been submerged in the base line of the graph; you wouldn't have been able to detect it, so I did it this way to make it more clear.

That is the record of the Foundation so far. And we note that if the administration's budget is approved, funding for science education would shrink to a mind-boggling 9$^{1}/_{1000}$ of the total NSF budget, and as we can all foresee, would soon shrink to zero. I think this is a sharp change, but as you look at this graph you see it is not that sharp a change from past policy. It is clear that the Office of Management and Budget and possibly the Foundation itself have not supported science education over a long period of time. And we can't blame this, as the previous Director did, on a decline in college enrollments, because college enrollments have been going up until this year they may be peaking, but this decline in science education support preceded any decline in enrollments.

So it seems to me as Representative Brown implied at an earlier session and Representative Dymally this morning, that what is being proposed here is a violation of the Foundation mandate. I am not a lawyer; I don't know whether it is legal or not, but any logical person would conclude as I did: if you have no money, you have no program, and if the mandate says you should have a program, then you are in violation of it.

I also think it is incorrect to assume that somehow this is only a temporary halt and if we only wait awhile, a few years, it will come back again. Things don't come back very easily in the kind of economy that we have today.

Let me just summarize by saying that the colleges I represent have consistently expressed the point of view that if in the national interest budgets must be restrained, then the changes should fall proportionately on basic research on the one hand and on science education on the other. Why must we make an already deplorable situation worse by first cutting and then zeroing out science education while allowing increases in the budget overall? We are willing to share in the President's effort to improve our national economy, but we do not believe it is in the national interest for science education to be annihilated. To be more specific, if according to the second Reagan plan the total NSF budget for 1981 is to be increased only 2.5 percent over 1980, then let the provision for science education be increased by 2.5 percent. That would take it up to $79.1 million. Similarly, for fiscal 1982, the Reagan budget that we have just seen envisions an increase of another 2 percent, and so let the science education budget increase by the same 2 percent.

We are willing to stay where we are. We just want to survive. It is clear these slight increases would not improve what is a really sorry state, but at least they would allow us to have a holding action for a few more years. I would caution, however, that if it is possible that this committee and the Congress can maintain this kind of funding, the Congress should be willing to look very closely at individual programs, the ones which sustain and maintain excellence in science education, and give them priority in this decreased budget. Beware of new programs that come in like the funding for engineering equipment that suddenly goes from zero to $25 million. I am in favor of some funding for engineering education, but it seems to me that is too much too rapidly. Beware of the proclivity of the Foundation to go for the trendy rather than the solid and proven programs, the ones Dr. Roaden mentioned.

For the long run, I would just repeat, that we would like to see funding for science education gradually brought up to a reasonable fraction of the basic research budget. As you can see, back in 1967, it was about half of it. It is now shrunk to 9⅟₁₀₀₀. We would like to see it up to maybe one-third as a reasonable fraction, and then we would like to see Congress insist that it stay at that fraction, and as the NSF budget goes through its up and downs, we wouldn't have to have these prolonged testimonies every year.

In summary and finally, we believe that the future of our national defense and industrial technology are dependent upon high-quality science education. And everyone who has been here has said that. As for the scientists and technologists of the immediate future, we know where they are: they are in our elementary schools, and in our high schools, and our colleges. Instead of cutting back this lifeline to our future safety and economic well-being, we should be repairing the shortfalls of recent years already evidenced by our citizens' eroded understanding of science and mathematics. If budget cuts must come, it cannot be in the national interest to have them fall disproportionately upon science education.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Powell follows:]

Statement by

Dr. James L. Powell
Vice-President and Provost

Oberlin College

On the

Fiscal 1982 National Science Foundation Budget Authorizations

On Behalf of

The Great Lakes Colleges Association

and

The Other Members of the Independent Colleges Office

Before the

Subcommittee on Science, Research and Technology

Committee on Science and Technology

U.S. House of Representatives

2325 Rayburn House Office Building

March 10, 1981

Chairman Walgren, Members of the Subcommittee:

I am very grateful for this opportunity to testify before you as you begin review of the National Science Foundation budget for 1982. I represent the sixteen independent colleges and universities which share the Independent Colleges Office,* and I believe my views would be supported by colleagues at other similar institutions across the country. I speak from my background as a graduate of both a four-year college and a major technical university, as a teacher of science, a published researcher, and currently as a college administrator.

This Subcommittee has played a vital role over the past few years in helping to protect and strengthen the Nation's effort in science and particularly in science education. Former Representative Charles Mosher and, more recently, Representative Don Pease, both from my district in Ohio, Representative Fuqua, Representative Brown and other members of this Subcommittee understand that a country without a strong program of science education simply cannot win out in this age of emphasis on technology-based productivity increases, of an energy crisis, of increasingly sophisticated weaponry, etc.

The science education community once again needs to call on this Subcommittee for leadership and guidance. Many of us are in a state of shock at the proposed closing down of the Science Education programs of the National Science Foundation. We were prepared to face, with you, what we read as the popular mandate to trim Federal spending. But how can we beef up national defense and industrial productivity if we abandon the training of the people who must be responsible for both? Science is not a state or local issue: It is a national concern and a national responsibility.

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*The Independent Colleges Office is the Washington Office of the Great Lakes Colleges Association whose members are: Albion College, Antioch University, Denison University, DePauw University, Earlham College, Hope College, Kalamazoo College, Kenyon College, Oberlin College, Ohio Wesleyan University, Wabash College, The College of Wooster. Other Independent Colleges Office members are: Beloit College, Mount Holyoke College, Reed College, Rollins College.

In my testimony I will

1. Review the mandate of the Congress to the National Science Foundation, specifically as it concerns science education;
2. Examine the extent to which that mandate has been fulfilled;
3. Summarize the Administration's proposed budgets for Science Education in fiscal 1981 and 1982, and
4. Propose a budget for Science Education that reflects both the need for austerity and the Congressional mandate regarding Science Education.

NSF Mandate

The National Science Foundation functions under a mandate from Congress " . . . to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences." The Foundation is " . . . to initiate and support . . . programs to strengthen scientific research potential and science education programs at all levels . . . ."

These words were chosen with care, and I believe that Congress should see to it that their meaning is reflected in the actions and budget of the Foundation. For example, the explicit use of "at all levels" takes account of the essentially continuous nature of science education: What takes place at one level is important for the next highest level, and so on up to the most specialized graduate research program. Within this spectrum the undergraduate level of science education is of particular significance; poor quality here is amplified with disastrous effect. Not only does a particularly talented subset of young people receive preparation for graduate studies in science, but another subset prepares itself to enter immediately teaching careers at the elementary and secondary level, and still another subset takes its last course in science during these undergraduate years.

I submit that the close connection between quality science education (in one generation) and quality basic research (in a later generation) and the explicit NSF mandate for support of science education quoted above are of fundamental significance for any discussion of the goals of specific Foundation programming in science education. This has, in fact, been acknowledged by this Subcommittee many times before: There is a continuity in the process of science education and in the strategies for developing first-rate scientific talent, which makes nonsense out of any sharp demarcation between, for instance, the graduate level and the undergraduate level.

The words " . . . to initiate and support . . . " require that the Foundation give due attention both to the innovative and to the sustenance of the on-going process of science education. Neither is favored over the other in the mandate. Although at times the Foundation has seemed to be irresistably attracted to the trendy, we do acknowledge that it has understood that quality science education always has required and always will require certain basic ingredients: First, well-trained faculty and teachers; second, excellent modern curricula; third, up-to-date and well-maintained equipment and, fourth, able and well-prepared students. The Foundation has done an excellent job in developing programs which speak to these needs:

+ For well-trained faculty and teachers, Science Faculty Professional Development, College Faculty Workshops, Pre-College Teacher Development and Summer Institutes;
+ For modern curricula, Local Course Improvement, Comprehensive Assistance to Undergraduate Science Education and Development in Science Education;
+ For educational instrumentation needs, the Instructional Scientific Equipment Program, and
+ For able students, Undergraduate Research Participation, the Student Science Training Program, and Graduate Fellowships.

This Subcommittee must continue to see that these vital programs survive despite efforts to trim them in favor of others that can be called innovative or crisis-responsive. Crisis-response programs, such as those added in the Carter Administrations's fiscal 1982 budget to aid in the productivity of engineering teachers, may be justifiably added to the core programs but must not divert from the basic and continuing need to produce good scientists in all disciplines. Past history indicates that start-up programs should begin with modest funding and increase over a three- to five-year planned period as justified by careful evaluation and productivity studies.

What has been the recent record of the Foundation in strengthening Science Education programs? How has the NSF budget reflected that Congressional mandate? The answers to these two questions are: "Abyssmal" and "It hasn't." The evidence presented in Appendix A shows how support for the total NSF budget and for Science Education has now diverged to the point where the budget for Science Education is a mind-boggling nine one-thousandths of the total NSF budget for fiscal 1982. (We have necessarily relied on unauthorized data for the Administration's most recent 1982 figures and we hope to confirm them later for the record.) This decline in funding for Science Education was not caused by any dropoff in college enrollments, for it began more than a decade ago when enrollments were climbing. We believe that the explanation is simply that the Foundation and the Office of Management and Budget have elected to emphasize support for Basic Research over that for Science Education in direct contradiction to the mandate. The Science Education budget in the current plan for fiscal 1981 is only 7.4 per cent of the total NSF budget. The Administration proposes in its revised fiscal 1981 budget a cut of $16.0 million to reduce Science Education to a 6.3 per cent share. For both fiscal 1981 and 1982, the proposed NSF total budgets represent an increase over the previous year -- yet Science Education has first been cut back and then annihilated!

Representative Brown asked an earlier witness in these hearings if he regarded the elimination of the Science Education programs as "against the [enabling] law." We will answer that question: Yes. We strongly urge that Congress set a firm ratio for Science Education support to Basic Research support, one-third, in order to avert in the future this sort of surgery which could lead to a perilous decline and failure in scientific manpower.

State of Science Education in the Nation

We cannot say to what extent the shabby treatment afforded Science Education by NSF and OMB is responsible but the evidence is ample that science education in the nation and the capacity of our citizens to cope with an increasingly technological world are in a very sorry state. For example, the most recent National Assessment of Science conducted under the auspices of the National Institute of Education shows a continuing decline in the science achievement of nine-, thirteen-, and seventeen-year-olds. The decline in the mathematical Scholastic Aptitude Test (SAT) scores for College-Bound Seniors has been twenty-six points in the last thirteen years. (Appendix B.)

The recent report on Science and Engineering Education, "Science and Engineering Education for the 1980's and Beyond," produced commentary in The New York Times, The Washington Post, Science magazine and elsewhere. The report showed that the minority of students who plan careers in science or engineering are learning as well as ever. But the majority of students, the nonspecialists, are dropping science and mathematics courses sooner than they used to and getting poorer scores on tests. Too many are leaving school as scientific illiterates, thus worsening the "two cultures" gap about which the late C.P. Snow spoke. "We fear loss of our competitive edge," the report said, concluding that the United States lags behind the Soviet Union, Japan and West Germany in elementary and secondary school programs in science and mathematics. More than 5 million Soviet students take calculus in high school; only 500,000 here take it by the first year of college. As The Times says in a cool display of understatement, "At some point, such a disparity will become important."

Platform of the Republican Party

Those concerned with the quality of education in this country, and especially with science education, began to hope a little when we noted that the Republican Party stated in its platform that it is "determined to restore . . . quality to education" and noted that "America has a great stake in maintaining standards of high quality in education." Other portions of the platform dealing with productivity, with energy and with defense gave us hope that a connection between these vital areas and a strong program of science education would be perceived. Alas, we appear to have been wrong.

Administration Budget

Appendix A shows our summary of the recent, present and future budget allocations for the Foundation as a whole and for Science Education. President Reagan's original fiscal 1982 budget (February 18, 1981) would have been lower than the 1981 provision for Science Education, already far too low, by $16.0 million. Science Education would have received for 1982 only $64.9 million, thus lowering its percentage of the total to 5.8 per cent.

Even with a decrease for the Behavioral and the Social Sciences, the allocation for Basic Research programs would increase by 9.1 per cent between current plan 1981 and the February proposed budget, as opposed to the Administration's stated policy of holding growth of Federal spending to six per cent. If the axing of Science Education now proposed for 1982 were to be sustained, the Administration will have found a total of $75.9 million to put elsewhere in the NSF budget. Once again, Science Education is made to suffer while funds for research increase.

As an aside, we do not understand the low priority for the Behavioral and Social Sciences. As Lewis Thomas, the scientist-author has said, "Our behavior toward each other is the strangest, most unpredictable, and most unaccountable of all the phenomena with which we are obliged to live. In all of nature, there is nothing so threatening to humanity as humanity itself." Surely this is not a time to restrict disproportionately funding for these areas.

The Administration's budget probably permits no funding at all for the special program of support for research equipment for two- and four-year colleges. We believe that the small number of women in science careers is also a legitimate crisis deserving NSF's attention and support.

Our Proposal

The colleges I represent have consistently expressed the point of view that, if in the national interest budgets must be restrained, changes should fall proportionately on Basic Research and on Science Education. Why must we make an already deplorable situation worse by cutting and then zeroing out Science Education while allowing increases in the budget overall? We are willing to share in the President's effort to improve our national economy, but we do not believe it is in the national interest for science education to have to bear an annihilating share of that burden.

Specifically, if according to the second Reagan plan the total NSF budget for 1981 is to be increased only 2.5 per cent over 1980 to $1,021 million, then let the provision for Science Education be increased by the same percentage over 1980 to $79.1 million. Similarly, for fiscal 1982, the Reagan budget envisions an increase of 2.0 per cent for the total budget over the projected 1981 budget and, therefore, the Science Education budget should rise to $80.7 million. These slight increases will not improve the present sorry state of science education cited above but if they are necessary in a program of austerity, then we will try to live with them. If inflation can be halted, such a holding pattern for the immediate future will at least lead to no further erosion. *However, Congress must be willing to look closely at the individual programs which sustain and maintain excellence in science education and give them priority in a decreased budget.* When Congress restores the Science Education programs, we look to you to set priorities so that coping with new crises (for instance, the engineering education initiatives) will not cripple other vital NSF programs.

For the long run, we repeat our request that funding for Science Education should be brought gradually to a reasonable fraction of the Basic Research budget, and then held there through the ups and downs of the annual budget cycle. We suggest one-third, far less than the one-half that existed in the late 1960's.

In summary, we believe that the future of our national defense and industrial technology are dependent upon high quality science education. The scientists and technologists of the immediate future are in our secondary and undergraduate schools today. Instead of cutting back this lifeline to our future safety and economic well-being, we should be repairing the shortfalls of recent years already evidenced by our citizens' eroded understanding of science and mathematics. If budget cuts must come, it cannot be in the national interest to have them fall disproportionately upon science education.

Appendix A

NSF Actual and Proposed Budgets, Fiscal Years 1980, 1981, 1982

	Actual FY 1980	Current Plan FY 1981	Reagan Request FY 1981	Carter Request FY 1982	Reagan Request (2/19/81) FY 1982	Reagan Request** (3/10/81) FY 1982
NSF TOTAL	996.3	1,096.0	1,021.0	1,353.5	1,117.0	1,041.9
NSF Science & Engineering Education	77.2	80.7	64.7	111.9	64.9	9.9
NSF Research:						
Mathematics & Physical Sciences	227.0	257.1	257.1	301.3	301.3	n/a
Engineering	76.6	86.8	86.8	104.6	104.6	n/a
Biological, Behavioral & Social Sciences	185.7	198.1	183.1	219.0	175.0	n/a
Astronomic, Atmospheric, Earth & Ocean Sciences	218.1	236.2	236.2	268.0	268.0	n/a
NSF Basic Research TOTAL	707.4	778.2	763.2	892.9	848.9	n/a

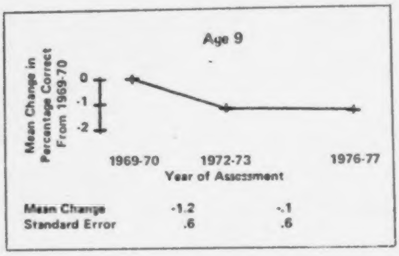
Sources: Statement of FY 1982 Budget, National Science Foundation, NSF PR81-4.
Reagan Administration Budget Requests, February 18, 1981.

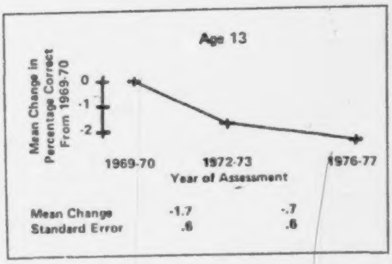
Independent Colleges Office
March 6, 1981

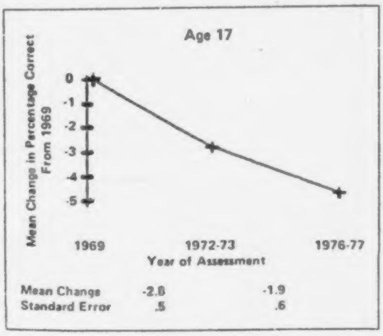
**We have necessarily relied on unauthorized data for the Administration's revised 1982 figures and we hope to confirm them later for the record.

Appendix B

Changes in Achievement 1969-1977
Three National Assessments of Science







Source: National Assessment of Educational Progress, Education Commission of the States

Changes in SAT Average Scores for College-Bound Seniors 1967-1980

SAT Score Averages for College-Bound Seniors, 1967-1980*

	Verbal			*Mathematical*		
	Male	*Female*	*Total*	*Male*	*Female*	*Total*
1967	463	468	466	514	467	492
1968	464	466	466	512	470	492
1969	459	466	463	513	470	493
1970	459	461	460	509	465	488
1971	454	457	455	507	466	488
1972	454	452	453	505	461	484
1973	446	443	445	502	460	481
1974	447	442	444	501	459	480
1975	437	431	434	495	449	472
1976	433	430	431	497	446	472
1977	431	427	429	497	445	470
1978	433	425	429	494	444	468
1979	431	423	427	493	443	467
1980	428	420	424	491	443	466

* The averages for 1967 through 1971 are estimates of the averages that would have been reported for college-bound seniors of those years if such reports had been produced.

Source: "National Report: College-Bound Seniors, 1980," Admissions Testing Program of the College Board

Mr. **Walgren**. Thank you very much, Dr. Powell.

I understand, Dr. Marston, you have an appointment, and I think that would be a very valuable appointment for this whole subject matter. I don't want to delay that.

I wanted to ask you whether the University of Florida has participated in any of the instrumentation grants that might have been made in the past.

Dr. **Marston**. Yes; $2 million this year—$3 million this year and $2 million the next, I guess. And we have also participated in the review of needs, and the needs are very high. We are a modest-size university, I guess, if you look across the land, 31,000–32,000 students, but heavy in science and technology and agriculture and medicine. So our figures, in terms of needs, are high.

Mr. **Walgren**. Well, thank you very much. I don't want to keep you from your scheduled appointment.

Dr. **Marston**. Thank you very much.

Mr. **Walgren**. Mr. Pease?

Mr. **Pease**. Mr. Chairman, let me just thank you for allowing me to return to this subcommittee from whence I fled a couple of months ago to join the Ways and Means Committee.

I would like to welcome Dr. Roaden, and especially my neighbor, Dr. Powell, to the subcommittee.

I don't think I could say it better than Dr. Powell has already said it. It is extremely distressful to me that the National Science Board itself is not willing to stand up for science education, and we can't look to the National Science Foundation for support, either.

As many people know, this subcommittee has indeed been a defender of science education over the years, and I trust it will be again this year. I am happy to be on the Ways and Means Committee, but very unhappy that that membership caused me to have to leave this subcommittee. One reason that I am able to face that move with some assurance is the new chairman of this subcommittee, Mr. Walgren, has been a friend of mine for a long time and in my opinion is one of the most thoughtful members of the Congress. I believe that science education is in good hands as long as he is chairman of this subcommittee.

So again, Mr. Chairman, I just thank you for allowing me to come, and wish you well in the challenging job you have this spring, and tell you that I will be more than happy to support you in any way that I can.

And again let me thank Dr. Powell for coming today.

Mr. **Walgren**. Thank you, Mr. Pease. I especially appreciate those remarks. As some of you know, in the Congress some people are more equal than others, and the members on the Ways and Means Committee tend to be a little more equal than some of the others. So I think your move will be one which will increase the weight given to the priorities that you had on this committee, rather than deprive them.

I wanted to ask the minority staff if they had an area to pursue.

Mr. **Scoville**. Yes. Thank you, Mr. Chairman.

I do have just one brief question for you. Dr. Powell, I guess as I look at this thing, one has to recognize that the administration's decision to terminate science education is clearly a policy decision. It clearly is not just a matter of $70 million, or even $50 million.

The decision is that they basically feel that science education should not be a prime function for the National Science Foundation.

In your testimony you raised a contrary policy decision which is basically that you felt that science education should be around a third, 30 percent of the Science Foundation's budget. So we have two different philosophies about the balance of funding within the Science Foundation, irrespective of the absolute amount.

Now my question to you is if the Science Foundation's budget is to be, on the order of what the administration proposed or even, say, plus or minus $100 million or whatever it might be, should that balance be adjusted to your 30 percent for science education over a suitable transition time? Because that is the contrary policy decision about the basic structure. The administration judgment has been that it is not a part of the Science Foundation's mission. You have asserted the contrary position, and I would like to know in that circumstance, given the level of funding, would you propose a major sort of reorientation that would balance the Foundation's program?

Dr. POWELL. I think the conflict is between the congressional mandate which says research and education, not between me and the administration budget. I would propose that the fraction be brought up to some reasonable level, and a third seems reasonable, but over some long period of time. I am not proposing that in 1 or 2 years this be done. I would be satisfied to have the 2-percent increase that I mentioned that would be proportionate to the overall increase in the Science Foundation budget. We are willing to maintain the fraction we have now until, as we all hope, the economic conditions in the country become better.

Mr. SCOVILLE. So in other words, you would only advocate that different balance if the overall Science Foundation budget grows?

Dr. POWELL. If the overall Foundation budget cannot grow, we woud be satisfied to stay at the fraction we have now.

Mr. SCOVILLE. OK. That is all I wanted to know.

Mr. WALGREN. Thank you, Mr. Scoville.

Mr. SCOVILLE. Thank you, Mr. Chairman.

Mr. WALGREN. Well, I appreciate very much your coming and testifying. And you have filled out the views that were presented earlier from the university standpoint very significantly. The committee appreciates your effort very much. Thank you.

At this point I should like to insert in the record several letters and statements that bear directly on today's hearings.

Hearing adjourned.

[Whereupon, at 12:58, the subcommittee was adjourned.]

[The material mentioned above follows:]

SweetBriar College

Office of Government Relations
and Sponsored Programs

1701 K Street N.W., Suite 701
Washington, D.C. 20006
(202) 659-2104

March 9, 1981

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research & Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

On behalf of Sweet Briar College in Virginia, Wellesley College and Williams College in Massachusetts, and Bethany College in West Virginia, I submit the attached statement related to the Education Directorate of the National Science Foundation. I have been asked to request that this statement be included in the record of the hearings.

The concern of these colleges echoes that of many more who deplore the inequitable budget cuts projected by the Reagan Administration for the Science Education Division of the National Science Foundation and who will write directly to the Committee and to their own Representatives.

Sincerely yours,

Julia M. Jacobsen
Director of Government Relations
and Sponsored Programs

JMJ:ta

Attachments: Statement of Harold B. Whiteman, President, Sweet Briar College
Telegram from Judith Allen, Williams College
Letter from Maud H. Chaplin, Acting President, Wellesley College
Letter from Hiram J. Lester, Director of Development, Bethany College

SweetBriar College

Sweet Briar, Virginia 24595
President's Office

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research & Technology
U.S. House of Representatives
Washington, D.C. 20515

Mr. Chairman:

I address you as President of Sweet Briar College, and join with my colleagues from other independent liberal arts colleges in expressing our united concern that the Education Division programs of the National Science Foundation be reauthorized and strengthened with increased appropriations. Sweet Briar College currently enrolls 690 women from 40 of the 50 states and many foreign countries in its four-year program leading to the bachelor's degree. Over 30 percent of our graduates continue on to graduate study with an increasing number of these young women seeking advanced degrees in law, medicine, engineering, computer science, and management. The College has operated in the black since its founding in 1901. Federal student financial assistance helps assure diversity of the student body, but we are not dependent on Federal support for operational costs.

A college must operate with fiscal responsibility. We cannot afford major outlays for equipment and related faculty training any more than most businesses and industries can afford the cost of basic research for the general good. Yet the changes in undergraduate science education must be on the "cutting edge" if we are to prepare students for the challenges of a technologically oriented society.

There are costs beyond the means of an institution which are essential to keep pace with new knowledge and new technologies. The National Science Foundation has been a vital resource to undergraduate science education. The competitive grants awarded on the basis of peer review have provided essential support for modern laboratory equipment and computer hardware. Periodic infusions of large sums of money will continue to be needed for acquisition of complex configurations of scientific equipment essential to the advanced level of preparation required for students going on to graduate study or directly into business and industry. New developments and new technologies also require major revisions in the curriculum and special training for faculty. The rapid development of computers as tools for instruction as well as for data collection and analysis has placed a costly burden on every institution of higher learning to acquire such equipment and revise courses affected by the new computer-based instruction.

Computers and related curricular change are but one example of the costly developments required of science and engineering at the undergraduate level. During the last ten years Sweet Briar College has received $514,900 in support from NSF for these major projects: A computer main frame and faculty training for the Tri-College Center of Virginia; revision in the curriculum and modern equipment for 7 departments to develop an Environmental Studies Program; support to integrate computer assisted and computer based instruction into the curricula for sociology, mathematics, psychology, government, physics and chemistry.

In addition to these major grants we have had over $65,000 in grants for Local Course Improvement and Instructional Scientific Equipment. Faculty have taken full advantage of Federal Excess Property to further stretch their resources.

This support has come through the Comprehensive Assistance to Undergraduate Science Education (CAUSE), Local Course Improvement and Instructional Scientific Equipment programs (LOCI and ISEP). Students have been involved both in the classroom and laboratories and in summer research activities. The Undergraduate Research Participation (URP) helped provide support for the latter. We are not concerned with "getting the government off our back" in the case of the National Science Foundation. To the contrary, the Foundation is a source of support for the college teacher's curricular and professional development. The design of such work is self-determined in precisely the same manner as the work of the research scientist. In addition, the Foundation has increasingly become the banker for information on science education developments in institutions of higher learning all over the country. Access to such information has led to the adaptation of many developments to our own needs. The source of information I refer to is that contained in the several directories of projects funded by the Education Division such as A Guide to Undergraduate Science Course and Laboratory Improvements.

To give you a very specific idea of the kind of support we want to see continued for the good not only of this institution but for the good of science education and ultimately the health of scientific enterprise in the United States, I will quote from a memorandum sent to me by Dr. George Lenz, Whitney-Guion Professor of Physics.

> "It would be difficult to overestimate the positive impact that Federal Programs have had on the science programs of the liberal arts colleges. I can think of at least 10 young women who graduated from Sweet Briar College in the last few years who have benefitted materially from some aspect of the federal government's concern for science education. These young women have all pursued successful careers in science or science related areas after graduation. I am not at all sure they would have made it or have been interested in science without this help. Programs such as College Science Improvement Program (COSIP), CAUSE, LOCI and Student Originated Studies (SOS) and any number of others supporting science education have provided the principal means by which the faculty at small institutions have been able to keep abreast of the rapid changes which have taken place in knowledge, technology and instrumentation. Without the

support of the federal government an important part of the scientific infrastructure of this country would have withered and died. We are living in an era in which scientific and technical competence provides the basis for our national strength. It would be foolish and unconscionable to emasculate science education in a time of national trial. The wise farmer saves the wheat while discarding the chaff.

"With a grant from the Comprehensive Assistance for Undergraduate Science Education (CAUSE) program, we have been able to introduce the new computer graphics technology into the undergraduate physics curriculum. Students have been enabled to conduct experiments through simulation which could not otherwise be done in the laboratory. For example, we can simulate the motion of planets, satellites and near-surface rockets in an inverse square force field. Students can interact directly with the computer and by changing the parameters of the experiment observe how, for example, velocity affects the orbital path of a satellite. In the process of developing the materials for the computer graphics, a consultant put us in touch with another NSF grantee doing similar work. NSF staff and publications on their project support have put us in touch with others working in the same field resulting in immediate exchange of information on new technologies. These contacts with others in the field have been very important to those of us who teach in small colleges."

Attached are telegrams and letters from Wellesley, Williams and Bethany Colleges supporting my expression of concern for science education in our colleges and universities.

In closing, I urge the subcommittee to carefully examine the accomplishments of the education program of the National Science Foundation. I feel certain you will agree with us that the economies recommended for NSF would have a negative impact on the scientific enterprise in this country and would start a trend that will be very costly to reverse.

Respectfully submitted

Harold B. Whiteman, President
Sweet Briar College
Sweet Briar, VA 24595

March 9, 1981

western union **Telegram**

1981 MAR -8 PM 11:40

WDB045(2323)(4-017073S067)PD 03/08/81 2323
ICS IPMMTZZ CSP
4134584792 TDMT WILLIAMSTOWN MA 113 03-08 1123P EST
PMS JULIA JACOBSEN, MARCH 9 9:00 AM, DLR
1701 K ST NORTHWEST SUITE 701
WASHINGTON DC 20006

TALKED TO CHAIRMAN OF SCIENCE DEPARTMENT RE PROPOSED CUTS IN NSF. THEY SAID CUTS "DISASTROUS". LAST SEVEN YEARS HAVE RECEIVED $750,000 FOR NECESSARY EQUIPMENT-ANALYTICAL BALANCES, ULTRA CENTRIFUGES. [illegible] BUDGET CAN'T REPLACE OLD EQUIPMENT OR ADD NEW. MUST HAVE FUNDS TO KEEP CURRENT, ATTRACT BEST STUDENTS, GIVE QUALITY SCIENCE PROGRAM. ALSO RECEIVED UNDERGRADUATE RESEARCH PROGRAM FUNDS. BENEFITS STUDENTS GREATLY.

JUDITH ALLEN

NNNN

Wellesley College

WELLESLEY, MASSACHUSETTS 02181
(617) 235-0320 CABLE: WELLCO

Office of the President

March 3, 1981

Congresswoman Margaret Heckler
U. S. House of Representatives
2312 Rayburn
Washington, D.C. 20515

Dear Congresswoman Heckler;

You are no doubt aware that your district holds a disproportionate number of educators and students, a large percentage of whom are registered voters. As a member of that constituency, I am writing to express my strong objections to the drastic cuts proposed by the Reagan Administration for funding for the National Science Foundation and National Endowment for the Humanities.

In the past two years alone, grants from the NSF have enabled more than a dozen members of the Wellesley science faculty to purchase equipment and sponsor undergraduate assistants for major research projects which otherwise would not have been possible. Support from the NEH has funded the research activities of an equal number of our faculty in the humanities. In both cases, many projects are at the midpoint, with faculty members hoping for continuing support. In fact, nearly half of the funds now allocated to Wellesley by the NEH are for projects beginning in the 1981-82 academic year.

The proposed cuts for support of instrumentation and science education by the NSF will weaken the ability of colleges and universities thoughout the nation to deliver a current and comprehensive science education to all students. Furthermore, should the extraordinary cuts proposed for the NEH become a reality, the critical importance of the humanities in national and global policymaking will be gravely diminished. Modern equipment in scientific research is critical to the vitality of scientific inquiry. There are no substitutes, nor are there substitutes for the attention of a qualified faculty member in an undergradute research project.

As members of your constituency, the Wellesley College community looks to you to protect its vital interests in the area of education, and know that you will keep us in mind as you take a position on support for PELL Grants (BEOGS), Supplementary Education Opportunity Grants (SEOGS), College Work Study (CWS), National Direct Student Loans (NDSL), Guaranteed Student Loans (GSL) and support for the National Science Foundation and the National Endowment for the Humanities.

The higher education component is not only a key population in your constituency, but one of the most critical elements in the strength of the U.S. Please act to protect it.

Sincerely yours,

Maud H. Chaplin

Maud H. Chaplin
Acting President

cc: Edward M. Kennedy
Paul E. Tsongas
Joseph D. Early
Silvio O. Conte
James M. Shannon
Brian J. Donnelly

BETHANY COLLEGE
BETHANY, W. VA.
26032

March 6, 1981

The Honorable Douglas Walgren, Chairman
Subcommittee on Science, Research and Technology
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman,

Bethany College concurs in the judgement and testimony of Sweet Briar College and others relative to the proposed budget cuts announced for the National Science Foundation and the National Endowment for the Humanities. We would suppose that any agency knowledgeable and concerned about the viability of education to develop leaders for the future would share this concern.

The major problem with the proposed cuts, and we think these are devastating, are in the areas of curriculum advance and the training of competent scientists. For example, Bethany is presently developing and implementing a college-wide curriculum revision to teach critical thinking skills and improved writing to all undergraduates. This important development is the result of a small consultant grant from NEH. In 1980-81, we have been able to introduce a new course to teach science effectively to non-scientists because of an NSF-LOCI grant.

If college science laboratories do not stay with the state-of-the-art, the next generation of American scientists will fall behind the rest of the world. In recent years, a good research psychologist at Bethany has received equipment to update laboratories for student instruction in sociology and other behavioral sciences. Students have been able to learn current research methodology through new computer access and the chemistry students learn to use the latest spectrometric techniques of analysis because of a small laboratory equipment grant from NSF-ISEP.

If you have any questions, please do not hesitate to call me (#304-829-7723).

Sincerely yours,

Hiram Lester

Hiram J. Lester
Director of Development

University of Pittsburgh
CHANCELLOR OF THE UNIVERSITY

March 6, 1981

The Honorable Douglas Walgren
117 Cannon Street
House Office Building
Washington, DC 20515

Dear Doug:

I am taking this opportunity to reinforce the testimony you will hear on March 10 in support of the need to increase the nation's momentum in basic research and technological development.

There is no point in my repeating the vital arguments that link support for basic research to the future economic development of the nation. Instead I will emphasize an issue which may be of particular import and concern to the new administration as well as to Congress. There is a particularly urgent need to enhance the collaborative interface between industrial and university laboratories; the National Science Foundation and the National Commission on Research are providing useful guidance concerning objectives, obstacles, and model implementation programs.

It may interest you to know that I am taking steps to develop such a model program in Pittsburgh. I have recently discussed with representatives of Carnegie-Mellon University and leaders of the corporate community a program for developing a communications network and a strategy for increasing collaboration among our constituencies, particularly on energy related projects. I am also considering the establishment of an Applied Science and Technology Center here at Pitt and am seeking lead gifts for that purpose as a part of the University's current capital campaign effort. The new center would have a specific charge to foster research projects relating to energy, environment and health and which are viewed as mutually supportive of university and corporate missions. The center staff would seek to link social, biological and health scientists with natural scientists and engineers in the search for solutions to complex problems relating to technological development.

In light of the catastrophic drop in support that is projected for the social and behavioral sciences, I would like to make a special plea that the rationale for these cuts be given a careful review by the House Subcommittee on Science, Research and Technology. In the short run, for example, there are more people-related problems relating to energy development and use than there are prospects for technological solutions. Much effort has been expended over the past several years in bringing this message to the attention of governmental policy makers and institutions such as the Department of Energy and the Environmental Protection Agency. Only the trained social

PITTSBURGH, PA. 15260 (412) 624-4200

scientist can assess the impact of real or proposed policies on various elements of society, or predict or guide ways in which attitudes will affect outcomes or will be subject to change. The Reagan Administration also needs to be more clearly apprised of the contributions the social sciences can make to a host of other public needs through research.

I have placed emphasis on the above issue because it is the one most likely to get lost during the struggle to preserve hard science and technology budgets. Your public statements in support of a careful Congressional review of OMB budget cut proposals is immensely reassuring.

Doug, I am particularly encouraged and pleased that you now chair the House Subcommittee on Science, Research and Technology. I look forward to the opportunity to discuss science-related issues with you as the need arises and stand ready to provide all possible aid as you proceed with this most crucial assignment.

With best wishes for your continued success.

Sincerely,

Wes

Wesley W. Posvar
Chancellor

The MATHEMATICAL ASSOCIATION of AMERICA
INCORPORATED

Richard D. Anderson, *President*
Home: (504)926-2287

Department of Mathematics
Louisiana State University
Baton Rouge, Louisiana 70803
504-388-1666

February 23, 1981

Mr. Albert E. Murray
Committee on Science
and Technology
House of Representatives
Washington, D. C. 20515

Dear Mr. Murray:

I enclose a copy of the official reaction of the Science Education Committee of the Council of Scientific Society Presidents to the Hufstedler-Langenberg report. It is applicable to the hearings you are now organizing and does give some priortized recommendations.

We look forward to seeing you next Wednesday.

Sincerely,

RDAnderson

R. D. Anderson

RDA/jld
cc: James D'Ianni, CSSP
Peter Farnham, CSSP
encl: as stated above.

CSSP COMMITTEE ON SCIENCE EDUCATION

November 18, 1980

Reaction to the Report

"Science and Engineering Education for the 1980's and Beyond."

The report, directed to the President, is a useful document giving a comprehensive view of the status of science and engineering education in the United States. It was written after input of many individuals and organizations. The report focuses on a classical and somewhat narrow view of science and engineering education and does not adequately address education for those non-scientists or engineers involved in the use and application of modern technology. The report also inadequately addresses the issues of technician training in technical and community colleges. Thus, while properly recommending expanded and improved science education for the general voting public, it does not adequately emphasize the needs for quantitative and scientific orientation of future decision makers in business and industry.

In our judgement, the areas of science education to which the federal government should give top priority are those related to pre-college education. As detailed below, we believe that certain actions are indicated and demanded. Further we believe that, unless these education components are recognized as serious problem areas, they will not be able to compete for science federal funding. We wholeheartedly endorse significant federal efforts to address the problems identified.

1. Commission on Pre-College Education in Science and Technology

The report recommended the creation of a President's Council on Excellence in Science and Technology Education. While we endorse the establishment of this Council in principle, we believe its responsibilities, as suggested in the report, are not comprehensive enough to permit the Council to function as an influential body.

We recommend the establishment of a blue-ribbon National Commission on Pre-College Education in Science and Technology as described, in essence, in CSSP's October 14 memorandum to the Office of Science and Technology Policy. It should have two subgroups, one on pre-college education in the mathematical sciences and the other on pre-college education in the physical, life, and earth sciences. Given the importance of mathematics as a tool for the understanding of basic concepts in the natural sciences, these two subgroups should carefully coordinate their activities whenever possible.

Membership of the Commission should be comprised of both scientists and science educators including current pre-college teachers, in particular those with recognized ability to motivate students. There is growing evidence that the science community is ready for and even demanding a major commitment to science education, witness, for example, the education programs of both the American Chemical Society and the Mathematical Association of America.

The Commission should analyze the substantial existing data that have been accumulated in various recent studies of pre-college science and mathematics education. Beyond that, it should make explicit recommendations for action with priorities and cost analyses. The Commission should be organized and operated so that its recommendations represent a consensus of the science community and have major impact on federal spending priorities in the area as well as on state and local education agencies.

A pervasive problem which is becoming more acute and must be addressed is that of maintaining an adequate supply of qualified science and mathematics teachers in the classroom.

Items (2) and (3) below list two activities which we believe are of such urgency that they should be initiated at the earliest possible moment without awaiting action by the Commission.

2. Curricular Studies

We endorse the position in the report to the President:

> "New teaching materials in science and technology can be developed for the broad spectrum of elementary and secondary students... This is especially important for students in the middle and junior high schools. These curriculum materials could focus on the science and technology basis of essential national problems such as energy, national resources, and health. The National Science Foundation can build on existing activities to involve scientists, mathematicians and engineers in the enterprise, while the Department of Education can take the lead in involving education, and in helping school systems implement new courses and teaching approaches."

As an example of an area of current national need we cite pre-college education in the mathematical sciences. Strong pre-college mathematics training is fundamental to the training of all who seek to utilize effectively the results of the computer revolution now upon us, not just scientists and engineers. We need a much broader base of quantitatively-oriented people for the effective implementation of new technology in achieving innovation and increased productivity.

Since the curriculum revisions of 20 years ago, the computer age is changing the nature of what pre-college mathematics should be. Thus, the roles of computing and of probability and statistics as essential components of pre-college education need to be expanded. But even in elementary mathematics major changes are indicated; for example, the role of estimation is becoming much more important while some of the algorithmic processes of paper and pencil arithmetic are becoming less so.

There is further need for problem solving ability including data interpretation. There are striking examples of serious deficiencies in numerical awareness of even science and engineering-bound students at this time.

Accompanying any significant curricular change or reorientation of emphasis is a vital need for large scale teacher retraining and reorientation.

The need for curricular efforts in pre-college mathematics is only an example of similar needs in the other sciences.

No serious curricular efforts in any subject should be attempted without commitment to implementation of successful aspects.

3. Teacher Training and Retraining

We endorse the position in the report to the President:

> "The National Science Foundation can build on its long experience to support in service and summer institute programs and short courses to introduce experienced science and mathematics teachers at all levels to new curricula and the uses of computer and communications technology and to upgrade the skills of less qualified teachers. Such programs could be supported jointly by industry and could offer teachers experience in industrial settings as well as in universities."

We caution that such programs must be carefully designed to reflect current conditions. In designing these programs, funding agencies are urged to organize conferences of experienced school teachers and instructors who have taught in effective institutes or in-service programs, and scientists concerned with these issues. These programs must be subject-matter oriented and must include stipends, tuition, and subsistence expenses and/or salary bonuses for teachers participating in them.

GAITHERSBURG, MD., *March 20, 1981.*

Hon. DOUG WALGREN,
Washington, D.C.

DEAR CONGRESSMAN WALGREN: For the past several weeks I have been a fascinated, but not disinterested, member of the audience of your subcommittee hearings on NSF authorizations. I have children in school who have benefitted, and I hope will continue to benefit, from the government's involvement in science education so I feel that I have a vested interest in the outcome.

I really should have know better, but I had expected to find the committee the villain and instead I found a group of people who understood the problem, wanted to find the right answers and were presistent in probing the witnesses. I was so impressed that I wanted to write all your constituents and tell them that they are getting their money's worth and more. (I am a precinct chairman and we think our congressman, Mike Barnes, is very special.)

There are several points I would like to make concerning the testimony given. It was said that the private sector and local governments would pick up where NSF left off. The local schools (Montgomery County) were given computers by the PTA and we were attempting to find instructors for the children as none of the teachers were able to use the computers and/or teach the children to use them. We asked a professional from a near-by computer facility if he, or anyone he knew, could help us. His reaction was—heavens! Teach children to use computers! Not done! A friend of mine taught herself and did it on a volunteer basic and now charges a small fee for her classes. However she is only able to teach a small fraction of the students who are interested. If one of the best school systems and the best computer company cannot buy computers and teach the children to use them, I have little faith in the rest of the system's ability to take up the slack.

My other experience with the same computer company was with one of their top men who taught (moonlighting) at the community college. The class was so poorly taught that the only students left at the end of the semester were those whose company had paid the tuition. What is important to remember is that not everyone can teach and those who can teach are underpaid and under-appreciated. They need all the help they can get in teaching science in a way that will excite the students and encourage them to pursue careers in science or at least realize that it exists.

Our daughters have had such positive experiences with NSF materials that I want to give my personal testimony. They (19 and now in college) went through the Unified Math Series (NSF) and without any precocious ability in math were able to score 750 and 690 on the Math SATs. Not bad for female twins—twins are traditionally underachievers. They also used NSF's Project Physics in high school and have no trouble with college physics or any other science courses (one is a chemistry major). Our third daughter. not so lucky, has epilepsy and is in special education. Her only science is "3,2,1 CONTACT" (NSF sponsored—excerpts were shown at the hearing) which we watch faithfully, and I might add that we have seen each program at least three times and are ready for some new ones.

I wish that some of the people giving such cavalier statements about the teaching of science and math would travel 25 miles from their offices and see the football coach teaching math (during the season he shows football movies). Those in control simply do not know what they are talking about. You may not be able to address that situation, but I hope that you can be instrumental in giving teachers adequate training and good materials so that they might not mind being on the bottom rung.

Thank you for your attention. I look forward to the next session. I feel that I am representing the children, waiting under the table for scraps from the grown-ups. I hope there are some.

Yours truly,

JAN WATSON.

1982 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, MARCH 12, 1981

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:30 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. Walgren. Today, the subcommittee continues its fourth day of authorization hearings for the National Science Foundation for fiscal year 1982. This hearing is focused on the behavioral, social, and economic sciences. In doing this, we don't want to be misinterpreted as having any lesser concern for other programs of the biology and behavioral sciences directorate, but simply that time constraints are limiting our focus, and in view of many of the proposals, this seems to be the area that we should spend a good deal of time on.

It has been said that the 1960's and 1970's were the period of major physical science and technological advances, while the 1980's should be the decade of the biological and the social sciences. There is ample evidence of our outstanding sophisticated high technology achievements of the past two decades. Certainly, recombinant DNA techniques, biotechnology, and biogenetics have given us evidence that the biological sciences are emerging with a potentiality that is vast in new genetic engineering industry for the 1980's.

In spite of these technological achievements, the mechanisms for more effectively transferring that basic work to the marketplace and for improvement of industrial innovation and productivity seem to elude us. Furthermore, we seem to have difficulty in correctly projecting and assessing societal effects, value and reactions to Government actions.

In the face of this, we have been presented with a proposed fiscal year 1982 NSF budget that seems to reflect a view vastly different in priority. Those areas we seem to need most—the social, the economic, and the behavioral—are the most severely cut in the proposed NSF budget. It will be interesting for the committee to hear the administration's arguments supporting those cuts.

We also have with us today a number of knowledgeable witnesses whose testimony will help our understanding of what may be at stake and to help us to put the programs of the National Science Foundation in appropriate perspective.

I want to welcome each of you and thank you for coming and giving your time to the committee.

Do any members have any opening comments that they would like to make?

[No response.]

Mr. **Walgren**. We will proceed directly to the first panel.

Again, we want to welcome Dr. Slaughter, the Director of the National Science Foundation, accompanied by Donald Langenberg, Deputy Director of the National Science Foundation, and also Dr. Eloise Clark, Assistant Director for Biological, Behavioral, and Social Science of the National Science Foundation, and Dr. Ernestine Friedl of the National Science Board.

We're particularly pleased to have a representative of the Board here. Your perspective means a great deal to us, and we want to thank you especially for coming.

Dr. Slaughter, please proceed as you feel best.

STATEMENT OF DR. JOHN B. SLAUGHTER, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. **Slaughter**. Thank you, Mr. Chairman.

Once again, we are pleased to have the opportunity to discuss with you and members of the subcommittee several aspects of NSF's program.

You have already introduced some of my colleagues at the witness table. I might add one or two words, so that the record is clear as to their positions.

Dr. Friedl, on my left, is professor of anthropology at Duke University and a member of the National Science Board. She is expert in a number of the areas that will be discussed this morning.

Dr. Eloise Clark, on my far right, is the Assistant Director for Biological, Behavioral, and Social Sciences. Dr. Donald Langenberg is Deputy Director of the Foundation.

After my opening remarks, all of us will be pleased to respond to any questions that you or other members of the subcommittee may have.

I believe you have received a copy of my testimony; I do not intend to read it. I believe, however, it does set forth the significance of the social and behavioral sciences to the overall mission of the National Science Foundation and the rationale for the budget being presented to you.

We think it is important that a special review of these issues be undertaken by this subcommittee. The administration's proposed budget for fiscal year 1982 makes major reductions in NSF's social science research support. Unquestionably, these reductions result from a need to reduce overall Federal spending. As a consequence, the National Science Foundation has found it necessary to reduce some of the spending planned in areas perceived to be of lower priority. It is important to convey to you, however, that we intend to maintain a significant program of research in the social science disciplines.

When NSF was established more than 30 years ago, the question of support for the social sciences was discussed. The Congress directed NSF to proceed cautiously with programs in these fields.

In 1953 a study was conducted to determine the most appropriate role for the National Science Foundation. With the support of the academic community, the National Science Board, and the Congress, we began the approach that led to the social and behavioral sciences becoming an explicit part of the National Science Foundation Act. In 1968 the Foundation Act was amended to include the social sciences among the scientific disciplines for which NSF provides research support.

We believe that NSF has established an important, vital relationship with the Nation's universities during the 30 years of its existence, and we are proud of that. We think the relationship must be maintained because the support of basic research has become an important responsibility of the Federal Government. That is no less true in other advanced nations in the world: England, France, the Scandinavian countries, West Germany and Japan. Such responsibility includes support for the behavioral and social sciences.

This year is the 21st in which a separate division of the National Science Foundation has been concerned with support for fundamental research in the social sciences. We can point to many successful products of that activity. We know much more about how the economy works; how societies and individuals develop, learn, organize themselves politically, socially and spatially, and how they change over time.

The causes, processes, and effects of social change represent a major focus of interest for the social sciences. It is important, we believe, to continue developing more knowledge and improving our understanding of the nature and implications of social change and human adaptations to it. The goal is always to learn more about how social phenomena occur, so that they can be understood and anticipated.

The primary disciplines included in NSF's social and behavioral science programs are anthropology, economics, geography, linguistics, political science, psychology, and sociology.

As you have pointed out, Mr. Chairman, representatives from some of these fields here today will be able to talk in greater depth about important activities in these fields. My purpose is not to replicate what they will be discussing but rather to talk about the unique role of NSF in the support of these disciplines.

We do not attempt to support all areas of research, given the wide range of activities within all fields of science and the involvement of other Federal agencies and the private sector in the support and use of social and behavioral sciences. Rather, NSF has concentrated on those activities which are concerned with fundamental theoretical or empirical interest, where NSF is not tied directly to any mission activity and where there is a promise of generalizations beyond the single problem or case.

The Foundation also has played a role as a source of support for objective analysis. A good example is Project Head Start, which was discussed at the Science and Engineering Education hearing 2 days ago. The National Science Foundation provided support for an objective analysis of Head Start materials. That work provided the definitive methodology for assessing the impact of early preschool training. The fact that it was carried out independently of those persons who were responsible for the program added a great deal to the objectivity and credibility of that particular analysis.

The point I am making here is that the research supported by the National Science Foundation is not directed toward proving or disproving particular positions regarding social policies or actions. The goal of that work is to understand human behavior and the operations of society.

We also discussed last week the interrelationships between basic and applied science. In social and behavioral sciences, the distinction between basic and applied research makes even less sense than in the physical sciences. In fact, many believe that the distinction is practically meaningless in the social and behavioral sciences.

Many investigations which started out to address applied policy problems have really led to major contributions to our basic knowledge; there is a long list of those investigations, intelligence and aptitude testing among them. Again most people concerned with the field of industrial research are familiar with the famous Hawthorne study of the Western Electric Co.; it helped learn more about how people operate in the work setting.

These studies were applied science because they were concerned with practical problems, but they also were basic science because they produced knowledge of general and lasting value.

We believe that a well-designed, high-quality, applied study can lead to improvement in our understanding of basic, underlying phenomena. Furthermore, we believe that broadly focused studies of the type supported by the National Science Foundation are much more likely to produce useful results.

Philip Handler made a statement that I would like to quote. He said, "Very suddenly we realize that man's activities are determinants in what the earth is and may be." The human dimension is important in understanding the energy shortage, productivity, the development of new technology, and the processes of innovation. We have to think of these issues in terms of their social context if we are to understand them.

The human factor is an indispensable ingredient of all that we do. New technology is greatly dependent upon the human ingredient. Without understanding the social and behavioral effects of what we do, we shall never be capable of revitalizing our society, no matter what technological innovations we may develop. Not only do we have to know how things work in nature, but we need also to know how they work in the society in which we live.

The resources of the National Science Foundation devoted to these kinds of issues have always been modest; rarely has the funding exceeded more than 5 percent of NSF's budget. Yet for some disciplines of the social and behavioral sciences, the Foundation is the only source of support for investigator-initiated, university-based research. But these individual project grants provide support for a large network of investigators all over the country. Foundation funding is important because it supports the longer range, higher risk, fundamental work essential to building the scientific base in the fields that I have mentioned earlier.

The limited funds available to us guarantee a competitive situation. About 20 to 30 percent of the proposals received in these fields are funded. And most are funded at 75 percent or less of the funds requested. Proposals are scrutinized through a peer review process involving ad hoc specialists and an assembled panel. The proposals are also forwarded through internal review. Our goal in these areas, as in other parts of the Foundation, is to see that only the most meritorious proposals are recommended for awards.

Mr. Chairman, we are beginning a new effort to restructure and consolidate our programs for fiscal year 1982 in view of the budgetary realities that we face. The National Science Board, during its next three meetings, will devote a considerable amount of time and energy to examining the support of social and behavioral sciences within the Foundation. NSF will continue to emphasize the longer term fundamental work devoted to producing new tools, new methods, and new information.

Mr. Brown entered the full text of Lewis Thomas' article on "Making Science Work" into the Congressional Record. I would like to quote just a few sentences of that work because I think it is particularly appropriate to what we're doing here today. It says:

> The social scientists have a long way to go to catch up, but they may be up to the most important scientific business of all, if and when they finally get down to the right questions. Our behavior toward each other is the strangest, most unpredictable, and most unaccountable of all the phenomena with which we are obliged to live. In all of nature, there is nothing so threatening to humanity as humanity itself. We need, for the most worrying of puzzles, the brightest of our most agile minds, capable of dreaming up ideas not dreamed up before, ready to carry the imagination to great depths.

Mr. Chairman, we at NSF believe that there is a great unity to research and scholarship. We have an underlying commitment to the value of inquiry: the discovery of new knowledge, new facts, and new relationships. There is an intellectual adherence to the standards of objectivity and verifiability that is shared by all scientific endeavors. We feel strongly that the social sciences are an integral part of this intellectual unity. They have been for many years, and they will remain in the years ahead an integral part of the National Science Foundation's program.

The administration's budget before you, Mr. Chairman, proposes reduced levels of effort in the social and behavioral sciences for fiscal year 1982. These levels are dictated by the need for strong fiscal constraints. We present the administration's revised budget to you and urge your support for these restrictions in Federal spending.

I would like to submit also for the record some reports on specific projects that have been supported in the social and behavioral sciences at NSF

[The prepared statement plus two reports submitted by Dr. Slaughter follow:]

Statement of

DR. JOHN B. SLAUGHTER
Director, National Science Foundation

before the

Subcommittee on Science, Research and Technology
of the
Committee on Science and Technology
U.S. House of Representatives
March 12, 1981

Mr. Chairman and Members of the Subcommittee,

I am pleased that you, Mr. Chairman, and your Committee, have put aside this time to concentrate on the social and behavioral sciences. It is appropriate that a special review of the Foundation's activities in these fields be undertaken.

The Administration's proposed budget for the National Science Foundation in FY 1982 makes major reductions in our social science activities. This is a result of the need to reduce overall Federal spending to meet the targets of the President's economic recovery programs. In this situation, we have been forced to reduce spending in areas of lower priority. We will, however, maintain a significant program of research in the social science disciplines. I would like this morning to give you some of the history and background of these programs.

The National Science Foundation was established by the Congress to strengthen scientific research potential in all fields of science. It has been responsible over the years for the health of academic science. From the earliest discussions that led to the 1950 Act that created the Foundation, the issue of the social and behavioral sciences has been addressed. At the time of initial passage of the Act, the Congress directed the Foundation to proceed cautiously with its programs in these fields. A study was begun in 1953 to determine the most appropriate role for the Foundation. During the ensuing years, new programs were developed following consultation with the academic community, the National Science Board, and the Congress. The approach was gradual and successful and was explicitly so recognized by the Congress in its amendment to the Organic Act in 1968.

A very important and vital relationship has been established with the Nation's universities and we assign high priority to maintaining it. The support of basic research in all fields has become primarily the responsibility of the government; this is a feature of most advanced countries that are in the forefront of science and technology. And the social and behavioral sciences are seen as part of that responsibility in England, France, the Scandinavian countries, West Germany, Japan and so on.

The year 1981 marks the 21st anniversary of the establishment of a separate division within the Foundation for the support of fundamental social science research. Concrete advances have been made during this period. We can point to gains in knowledge of how the economy works, how societies and individuals develop, learn, organize themselves politically, socially, and spatially, and how they change. The causes, processes, and effects of social change represent a major focus of interest for the social sciences. The perspective may differ, depending on the time span involved, the unit of analysis, and the particular behavior under study; but the core of concern converges on understanding the nature and implications of social change and human adaptations to it. The goal is to provide valid and verifiable findings on processes and consequences so that social phenomena can be understood and anticipated.

The primary disciplines included in the social and behavioral sciences at NSF are anthropology, economics, geography, linguistics, political science, psychology and sociology. You will hear later this morning from some outstanding representatives of a few of these fields. I will not attempt to characterize individually the scientific contents of these disciplines, but I would like to discuss the unique role of the Foundation with respect to them.

The Foundation does not attempt to support all areas of research, given the wide range of activity within each of these fields, and the involvement of other Federal agencies and other sectors in both the support and the use of social and behavioral rsciences. The Foundation's programs have concentrated on that small fraction which is of fundamental theoretical or empirical interest, is not directly tied to any particular mission interest, and promises generalizations beyond the single problem or case focus.

The Foundation also has served to fill an important need by providing a source of support for objective analysis. For example, NSF has made an important contribution to research which involved evaluating the results of Project Head Start programs. A grantee working on new methods of evaluation measurement reanalyzed Head Start materials and provided the definitive methodology for assessing the impact of early preschool training. The results have been well-received, and since they were carried out independently of those responsible for developing Head Start, they are much less subject to any suspicion of being self-serving.

This leads to a point I wish to emphasize: the research supported by NSF is not directed toward proving or disproving particular positions regarding social policies or actions. The goals are to understand human behavior and the operations of our social and economic institutions. That understanding becomes available to, and can then be used by, all segments of our society.

Another point relates to one that we discussed last week when we considered interrelations of basic and applied sciences. In the social and behavioral sciences this distinction makes even less sense than in the physical sciences. In fact, in the view of many social and behavioral scientists, the distinction is practically meaningless and the lines between the two are difficult, if not impossible, to draw. Many investigations which started out to address applied and policy problems led to major contributions to basic knowledge. Among these one can cite intelligence and aptitude testing developments, the opinion and morale work in World War II which led to The American Soldier, the distinguished series of research produced in industrial settings, starting from the landmark Western Electric studies, and the theoretical work made possible by data collected by mission agencies of the Federal government. These studies were applied in that they concerned practical problems; they were basic in that they produced knowledge of general and lasting value. The issue really centers on research quality and research design. A well designed, high quality applied study will be of interest and will have implications for basic research. Indeed, since a given applied issue may be of short duration and passing significance, broadly focussed studies are likely to be more useful to policy interests as well as being of greater scientific interest. I therefore believe that the merger of basic and applied efforts will be particularly beneficial in these fields.

As we look at the array of problems confronting our Nation and the world, it is quickly apparent that a common thread is the human dimension. "Very suddenly we realize" as Philip Handler has put it, "that man's activities are determinants in what the rearth is and may be." The long-term solutions to the energy shortage, productivity, new technology, and processes of innovation cannot be addressed without considering the individual and social context. Even in the way scientific research itself is conducted and organized and new scientific findings are adopted and utilized, there is an indispensable human factor. Without understanding social and behavioral effects more thoroughly, we will not be able to accomplish the task of revitalizing our society, no matter what technological innovations may be found. Just as we have to know how things work in nature before we can begin to use that knowledge, we have to know what is happening in society before we can develop appropriate responses.

The resources that the National Science Foundation has devoted to these aspects of research always have been modest. Rarely has the total exceeded 5 percent of the NSF budget. Yet the importance of our presence in these fields is substantial, far beyond the absolute sums involved. For some disciplines of the social and behavioral sciences, the Foundation is the only source of support for investigator-initiated, university-based research. The programs are not characterized by big installations, but by individual project grants that provide a network of investigators all over the country. In most areas, Foundation funding is important because it supports the longer range, fundamental work that is essential in building the scientific base of these fields.

Limited funds have always meant a very competitive situation. From 20 to 30 percent of the proposals received are funded, and most at 75 percent or less of the requested amount. Proposals are reviewed by ad hoc specialists and by an assembled panel. Recommendations are forwarded through several layers of internal review. This process assures that only the most meritorious objective work is recommended for award.

We are beginning another effort at restructuring and consolidating our programs for FY 1982 in the light of the budget you have before you. The National Science Board will devote part of its next three meetings to this topic, and we plan to rely heavily on members of the social and behavioral science community. The Foundation will continue to emphasize the longer term fundamental work that is devoted to producing new tools and methods, and producing new information that adds to our store of reliable, useful knowledge. In this sense, Lewis Thomas' article "Making Science Work" presents the future challenge for all of the sciences. Mr. Brown has entered the full text of the essay into the Congressional Record, and I commend it to you. Let me quote just a few sentences of Dr. Thomas' remarks on the social sciences:

> The social scientists have a long way to go to catch up, but they may be up to the most important scientific business of all, if and when they finally get down to the right questions. Our behavior toward each other is the strangest, most unpredictable, and most unaccountable of all the phenomena with which we are obliged to live. In all of nature, there is nothing so threatening to humanity as humanity itself. We need, for the most worrying of puzzles, the brightest of our most agile minds, capable of dreaming up ideas not dreamed up before, ready to carry the imagination to great depths . . . .

There is, I believe, a unity to all research and scholarship. There is an underlying commitment to the value of inquiry: the discovery of new knowledge, new facts, and new relationships. There is an intellectual adherence to standards of objectivity and verifiability that is shared by all scientific endeavors. Social sciences are an integral part of this intellectual unity. They have been for many years, and will remain in the years ahead an integral part of the programs of the Foundation.

The budget you have before you, Mr. Chairman, proposes reduced levels of effort in the social and behavioral sciences. The need for strong fiscal restraint necessitates our making some hard choices, and I believe we have made these choices correctly. I strongly urge you to sustain priorities and funding levels proposed in the Administration's revised budget.

Thank you, Mr. Chairman. I will be pleased to respond to your questions.

SOCIAL AND ECONOMIC SCIENCE AT NSF: CUMULATIVE IMPACT, CURRENT THRUSTS, AND PENDING ISSUES

Basis for Deciding Level of Support

How much support the Federal Government should expend for social science research depends, in part, on the value placed on the information, discoveries, and explanations that such research yields. Here the record becomes important. What achievements can be identified from past investments?

A summary of the usefulness and public importance of the social sciences is presented by Kenneth Prewitt in Science (February 13, 1981). He illustrates how social science has contributed to the public good through the technologies it has fostered, through the observational powers it has extended, through the knowledge it has developed, and through the tools and concepts it has brought into public discourse.

Clearly, the case for social science does not rely merely on findings from recent studies selected to reveal startling results. Social scientists are often pressed to emphasize novel features of their work. But there is more to scientific research than jolting findings, occasional breakthroughs, or rare revolutionary shifts. There is the painstaking process of discovery and explanation that builds knowledge incrementally as findings are tested and understandings are revised.

Knowledge of this sort is not divisible into private and public realms; it is a common good that requires public investments. Ultimately, costs must be measured against the gains in understanding and also against the risks of not proceeding with disciplined inquiry to discover just how social phenomena work and why social actions do not always work out as intended.

Each program in the Division of Social and Economic Science supports research that in the judgment of technical experts will add significantly to the fund of knowledge. Monetary, intellectual, and managerial resources are required. Government funding is augmented in the technnical review process by strong voluntary' support from the social science community. The concerted effort produces information, knowledge, and scientific explanations that are constantly updated by research thrusts that respond both to scientific curiosity and to changing national needs.

PROMISING PROBES INTO THE ECONOMY

Leads to the Business Cycle

The poor performance of the American economy during the last decade has elicited an intensive search for the underlying causes. The evident inability of the old policies to deal with current ills also stimulates new conceptual work that promises to yield a firmer basis for decisionmaking. NSF-supported studies are in the forefront of research efforts to respond to such concerns.

The burgeoning area of rational expectations research and the development of the new macroeconomics were born and nourished in NSF projects. This conceptual revolution, which includes the recognition that parameters change over time and over policy regimes, already has had important repercussions for macroeconometric modelling. But indispensable, empirically oriented work in this area is just beginning, as is the econometric retooling that this entails. A definitive theory of the business cycle, with its derivative econometric models, is likely to emerge from this sizeable research effort.

Aids to Decision Processes

Research in the economics of uncertainty and information is yielding promise of considerable progress. New developments play a significant role in the decision processes of business and Government when they deal with such problems as depletable resources, safety, and health. They also strengthen the ability to analyze previously intractable phenomena, such as insurance, research, and invention. But the harvest of this powerful analytic approach is still at an early stage of basic work, not to mention fruitful application.

Problems of Capital Formation

Although the low rate of investment in the United States has directed widespread attention to the problem of capital formation and related issues of productivity, systematic empirical studies are only beginning to pay off. A major long-term undertaking, funded by NSF, focusses on this crucial area. The work is being carried out under the leadership of Martin Feldstein of the National Bureau of Economic Research. Its wide scope includes complex investigations of taxation, research and developmennt, financial markets, international issues, and monetary economics.

Sources of Human Resources

Much of what is known about the economics of human resources derives from NSF-supported studies. One line of inquiry focusses on evaluating the economic importance of education and the analysis of its behavioral mainsprings. The research asks, what is the effect of formal schooling on an individual's life-time earnings and what are the underlying decision processes by which this human capital is formed? The identification and measurement of genetic, family background and other contributing factors is involved. The development of larger and more reliable data sets will be required for further advances in knowledge.

Another area of human resource economics, currently an issue of great policy importance, concerns the retirement decision and, more generally, the savings behavior of families and individuals. The careful modelling of savings and retirement behavior also requires a substantial investment in data development and "tool-making" in order to fully evaluate the economic well-being of the elderly who receive pension benefits and the systems that finance them.

THE CONTEXT OF ECONOMIC DISCOVERIES

The context for the thrusts noted above includes other concepts and findings clarified in research supported by the National Science Foundation over the years.

Prosperity and Aggregate Demand

The first two decades after World War II were years of remarkable stability and growth for the U.S. economy. From 1947 to 1967 the Nation's output almost doubled. Over this span, sustained technical progress contributed to annual increases in labor productivity in excess of three percent, while the consumer price index averaged a yearly rise of only two percent.

The theory and practice of macroeconomics in those prosperous times focussed chiefly on the determinants and stabilization of aggregate demand. There were two main issues for research, each a subject of political debate. What was the relative effectiveness of fiscal vs. monetary policy in the control of aggregate demand? Which is more effective in offsetting the instability of private spending—an activist use of discretionary policy or a noninterventionist policy relying on rules?

During the first postwar decade, monetary changes played a relatively small role in explaining fluctuations in aggregate demand. Fiscal policy was seen as the dominant instrument for control within a framework of Keynesian multiplier theory. Subsequently, the increasing importance of autonomous monetary movements prompted greater research attention to the potency of monetary policy, alone or jointly with fiscal actions. Toward the end of the 1960's, research findings pointed to the causal role of monetary changes in initiating fluctuations in aggregate demand. The term accorded this intellectual shift was monetarism. The debate between the so-called fiscal-activists, or Keynesians, and the monetary nonactivists spilled over into the research agenda of the seventies.

Inflation and Supply-Oriented Research

Monetary analyses and prescriptions began to flourish, but the economy soon encountered a series of severe shocks. These called in question the ability of the Government to insure a stable growth path of real GNP and employment, whether by monetary or fiscal measures. The appearance of supply factors as potential sources of macroeconomic dislocation substantially broadened the research framework. Responses to an externally imposed supply shock, such as a jump in the price of imported oil, are the prime data of such investigations.

A supply shock tends to raise prices and reduce total output. Government policy can cushion the impact of higher energy costs or crop failures on output. But such "accommodationist" policies tend to increase the rate of inflation. Alternatively, the Government can try to extinguish the inflationary impact of supply shocks, but this approach causes an even greater loss of output. The optimal degree of accommodation of supply shifts by policymakers remains a significant subject of inquiry. It appears that the choice between an accommodating, extinguishing, or neutral demand policy depends on the nature of wage-setting institutions and the international monetary regime, and, in the final analysis, on the perceived relative welfare costs of inflation and unemployment. These features and their variation over time and across countries are currently the subjects of empirical investigation.

Government-Induced Supply Shocks and Productivity

Another theme of supply analysis research centers on the decline of U.S. productivity. The multiple sources of this decline include changes in labor force composition, reductions in the rate of growth of the capital-labor ratio, and increasing environmental and other regulations. However, most of the retardation in productivity growth from the mid-seventies onward cannot be explained by these factors. The slowed rate of innovation may be a factor. Exactly how much is unknown, as are the reasons for the lag in innovations. Similarly, the accelerating rate of inflation may impinge adversely on productivity, but the nature and importance of this interaction still remain to be clarified through quantitative studies.

Increased attention in macroeconomics to supply factors also extends to their role in the exercise of public finance. Actions by the Government, such as increases in the minimum wage, in farm price supports, and in the scope and stringency of regulations amount to what Robert Gordon has termed "government-induced supply shocks." Supply-side theory suggests that their elimination or reduction will increase productivity and reduce costs. Just how much and how swift an improvement in reducing inflation and spurring growth can be realized from alternative cost-reducing fiscal changes awaits further research.

Taxes and Work Effort

The political centerpiece of supply-side economics is the Laffer curve. The underlying idea is that high marginal tax rates, at some point, destroy incentives to work, save and invest, and thereby cost the Government more revenue than they generate. However, the curve, as it applies to the U.S. economy, has not yet undergone extensive empirical tests.

The orthodox view is that the amount of work effort extended by American laborers is fairly insensitive to taxes. There may even be a "backward bending supply curve" since employees, when faced with rising tax rates, put in longer hours to maintain after tax incomes. Fragmentary econometric evidence indicates that taxes mainly affect the behavior of secondary workers rather than the bulk of the labor force composed of prime age males. But this conflicts with some new econometric information. The contradiction underscores the need for further systematic study. At this juncture there is no sound scientific basis for locating the economy on the Laffer curve. The U.S. may be on the prohibitive range of the curve (as Laffer contends) where tax rates stifle work activity so that total tax revenues fall. Or, the current elasticities of labor supply to after-tax changes in income may place the economy far below that negative segment of the curve. Though complex, the issue is researchable and of great importance.

Government Size, Savings, and Economic Growth

During the last century, the rate of net national savings in the U.S. declined from over twenty percent in the 1880's to less than eight percent in the 1970's. Over this same period, the Government grew tremendously. Outlays rose from seven percent to twenty-two percent of GNP. The size of the Federal debt, excluding social security, grew from less than ten percent to over ninety percent of GNP; and the level and structure of taxes was radically altered upward. Economic theory provides some qualitative predictions of the effects of these changes on national savings and economic growth, but the quantitative importance of these changes is little understood. The same is true about the impact of prospective changes in Government spending and taxation. As a result, many crucial issues of public policy are debated without an adequate factual or analytic base. The verification of scientific principles always lags behind the needs of public decisionmaking. High quality research can provide pertinent information and the analytic apparatus for evaluating alternatives in the public arena. Although research findings are not error-free, they are indispensable to enlightened decisionmaking.

Seeking the Sources of Spatial Organization

The primary objective of research in human geography is to advance understanding of the criteria, processes, and problems involved in the locational decisions of people, firms, and institutions that produce the spatial organization of society and economic activity. Traditionally, research has concentrated on the study of land use; the location of settlements, cultural groups, and economic activity; resource management; man-environment relationships; the migration of people; the movement of commodities; and the spatial diffusion of information. Recent geographic research has focused on location theory, regional economic development and stagnation (including urban regions), population redistribution, and the spatial analysis of social pathologies and public policy. Methodological emphasis is on improved variable specification and the development of computer simulation and micromodels of behavior in space.

Finding the Optimal Location

Many services, such as those provided by ambulances and fire-fighting equipment, are useful to the extent that they can quickly respond to calls. Clinics, hospital emergency rooms, schools and colleges, the farmer's grain elevator, and the urban shopping center also need to be optimally located for the efficient use of time and energy. Today, computer programs and mathematical methods of analysis are used to identify ideal locations. These approaches, developed by geographers and other social scientists with NSF support during the past ten years, include the use of mathematical theorems, special algorithms tested in a variety of conditions, computer graphics enabling visual presentation of demand data and of alternative planning schemes, and new modes of spatial analysis. As a result, decisionmakers in the public and private sectors can evaluate locations for different activities and decide which best meets defined criteria.

Important scientific questions remain concerning spatial-choice processes and the spatial organization of society. Geographic models and conclusions must be tested against comparative data from other countries to improve the value of theoretical conclusions.

NSF BUILDS AN INFRASTRUCTURE

The National Science Foundation has been a strong force in the development of the infrastructure of present-day social and economic science. That infrastructure includes the creation, maintenance, and accessibility of bodies of high-quality data upon which social and behavioral theories are formed, tested, and revised in light of verifiable evidence. Such data resources are shared by researchers across a spectrum of disciplines, as well as by analysts and decisionmakers seeking empirical information on various topics of public policy relevance.

Computerized Data Archives

In the mid-1960's, NSF began to support computerized social science data archives. Stored data resources were essential to advance the social sciences beyond the stage of individual scholarly artistry to the point of continuous cumulation of knowledge. Support was afforded to the then-nascent major U.S. data archives (e.g. the Yale Political Data Library, the Berkeley International Data Archive, the Roper Public Opinion Research Center), and funds were invested in the development of well-organized, economical, data-sharing enterprises such as the Inter-University Consortium for Political and Social Research.

By 1973, fifty percent of all graduate students in political science were receiving their training in quantitative methods through the Consortium. By 1976, a fair proportion of the methodological articles in the best social and behavioral science journals were authored by young Ph.D.'s who began their research under the aegis of the Mathematical Social Science Board, an adjunct project of national scope supported by NSF beginning in 1964.

Over that same period (1964-76), NSF also invested in developing both general-purpose and special-purpose software for data storage, management, dissemination, and analysis—the result of these efforts now manifest in the highly sophisticated state-of-the-art in archival technology.

Government Statistics and Survey Methodology

More recent initiatives insure methodological developments, substantive advances, and the quality of applied research fields utilizing social indicators and social accounting. High priority has been assigned to improving governmental statistics and survey methodology. Multiple projects have been launched to firm up the scientific base of the sample survey as a principal method of data collection. Organizational innovations are supported to anticipate the needs of the scientific community, to coordinate data production, and to undertake methodological studies necessary for the design and improvement of scientific measures. Two such innovations are concerned with making Federal statistics more responsive to current and emerging theoretical and policy concerns: the Center for Coordination of Research on Social Indicators (sponsored by the Social Science Research Council), and the NSF/Census Bureau Program of Research and Conferences to Improve the Government-Generated Social Science Data Base (sponsored by the American Statistical Association).

Amortizing Costs

NSF support has a large catalytic impact despite the fact that its effort is small relative to the total data production activity of American society. The cost of a single decennial census now reaches the one billion dollar mark. Other Federal statistical operations cost an estimated two billion dollars annually. Survey research expenditures (both Governmental and private) are estimated at between three to four billion dollars annually. NSF's relatively tiny expenditures for improvements in these and other data production activities have a wide impact on the quality, research relevance, policy-analytic usefulness, and accessibility of data whose collection was extremely expensive. The increased usefulness of these data helps to amortize a vast societal investment.

Adding Time Allocation to our National Accounting System

Among the pending issues to be addressed by NSF is the matter of expanded support for national studies concerned with time allocation, research that measures and monitors changes in the structure and quality of American life.

A comprehensive method of accounting underlies both the understanding and the interpretation of social and economic change in America. There seem to be three major "currencies"--money, people, and time. Data on money transactions and on people are systematically gathered by a variety of governmental agencies. Data on time allocation are not currently part of any periodic collection effort within the Federal statistical establishment. One important implication of this is the absence of household nonmarket activities from the national income and product accounts, making it impossible, for example, to guage the effects of shifts between market and nonmarket production on GNP.

Economists ~~interested~~ in measuring productive activity, the rate of change in real output, and the level of material well-being need to take into account a wider range of activities than those encompassed by paid employment. For example, housework, childraising, volunteer activities, maintenance and repair of housing, etc., all represent activities that enter significantly into any reasonable notion of income and output. To the extent that these activities take place outside of the market, they cannot be measured or analyzed with the aid of financial transaction data. An obvious substitute, imperfect but still useful, is data on the allocation of time, particularly where the data are collected in "time budget" fashion, indicating an exhaustive accounting of some slice of time in individual experience.

The measurement and understanding of time allocation requires much experimental work in the nature of developing reliable estimates for individuals, testing the incremental value of matched nondiary information, and exploring the collection and analysis of longitudinal data. The National Science Foundation thus continues to have an important role in furthering the methodology as well as insuring the viability of the highly significant time series it has fostered thus far.

FRUITS OF ORGANIZATIONAL RESEARCH

Linking Organizational Change and Labor Market Outcomes

Sociologists have long focused attention on large-scale organizations that occupy a crucial place in modern societies and on the processes of status and income attainment, which play an important role in the careers and well-being of individuals and families.

In the 1960's, significant progress was made in analyzing organizational growth, change, and decay. Advances were also made in understanding how labor market outcomes for individuals were affected by training, education, race, and other personal characteristics. Limitations in theory, methods, and data made it difficult to link labor force and organizational variables and to formalize knowledge about this interaction.

One important research development supported by the National Science Foundation in the 1970's brought these two streams of research together. Studies of status attainment and social mobility began to consider how labor market opportunities were affected by the social context and by employers' demands for labor. Analyses of organizations began to consider how management decisions affected the flow of personnel through the organizations.

Documenting How Labor Markets are Segmented

One line of analysis disaggregated the national labor market and described regional labor markets, industrial and occupational sectors, and even specific firms and organizations. Such inquiries documented labor market segmentation. The segments were internally organized by rules for entry and promotion. Such rules affect the opportunities for individual advancement. The size and rate of growth of employing organizations, and the composition of the labor force, helped to explain differentials in the distribution of income and other job rewards.

Productivity and Chains of Opportunity

The theoretical and methodological basis for much of the recent research on the links between the internal operations of organizations and job opportunities was presented by Harrison White in his Chains of Opportunity (1970). He conceptualized the process of labor mobility as based on chains of vacancies. Whether vacancies that occur in an organizational hierarchy are filled internally or from the outside and the rate at which they occur have significant consequences for turnover, worker productivity, and worker motivation. This research represents a fundamental reconceptualization of labor markets and attainment processes. Its contribution to understanding institutionalized sources of opportunity, organizational change, and effective use of labor are substantial.

Labor-Force Analysis

Robert Coles' research on Japan's labor force shows that with limited entry points, permanent employment, and few vacancies at any level, the costs of turnover to employer and employee are reduced. At the same time, motivation and efficiency remain high due to seniority rules and a system of deferred rewards. Productivity is high in part because there is little resistance to technological change. U.S. firms, in contrast, have a more flexible labor supply characterized by high voluntary and involuntary quit rates. There is also considerable resistance to technological change in the labor force..

Shelby Stewman's study of internal labor markets gauges the consequences of change in organizational size, age of workers, seniority distributions, and salary schedules. Using mathematical models of vacancy chains and labor mobility in firms, he demonstrates that a decrease in system size does not result in lower costs, even when holding salary schedules constant. The major factor here is an increase in the average salary of staff caused by seniority-related increases. Similarly, a policy of lateral recruitment, rather than internal promotion, results in significant additions to labor costs. It also affects worker motivation and firm productivity. These studies make it possible to assess, with increased precision, the impact of organizational characteristics and management decisions on employment opportunities and on the costs and benefits of different labor policies.

One of the current thrusts of the National Science Foundation is continued support of research bringing sociological theory and methods to labor force analysis. This will require additional research on sampling techniques and methods of analyzing job networks as well as application of increment-decrement models in demography to the labor force. Structural characteristics must be integrated with individual attributes to understand the complex relationships between labor supply and how the organization of demands affect employers and workers.

TOWARD A SCIENTIFIC UNDERSTANDING OF GOVERNANCE

Fostering a Behavioral Revolution

During the last twenty years marked change has occurred in the way that political scientists conduct their research. The result is an advance in the scientific understanding of basic political processes. Often referred to as the "behavioral revolution," politics is widely studied as an outcome of human interaction processes and decisions rather than merely as a product of legal statements and formal rules. Rigorous modes of explanation and analysis offer a contrast to conventional descriptive and literary approaches. NSF is the single largest supporter of systematic political research. Its important role is illustrated by developments in three subfields of the discipline.

Advancing on International Relations

In the field of international relations the National Science Foundation has supported several large collections of quantitative data on national capabilities and international interactions. These provide objective data for the test of numerous theories of international conflict. Morganthau's school of "real politik," for example, is inadequate to encompass the empirical regularties that occur in international relations.

Using a variety of approaches, research on foreign policy decision making supported by NSF has advanced knowledge about the structure of successful argument in international negotiations. Policy makers have "operational codes" that, once understood, are predictive of their responses to new events and situations, events that have definite and systematic consequences for the frames of reference used by the attentive public and foreign policy elites.

Learning from Comparative Politics

In the field of comparative politics, NSF support has helped change the general mode of analysis from single country case studies to systematic comparative work. Earlier studies seldom ventured beyond detailed descriptions of constitutional arrangements, election laws, and political history. Current work addresses the behavioral and institutional dynamics that influence the changing political contours of Europe, Japan, and the U.S. These studies monitor attitudes toward a stronger European community, Euro-communism, and the European Parliament. Quantitative studies use models to gauge the influence of economic structure and elite behavior on the development of interest associations, political parties, and worker strike behavior in Europe. A related thrust involves projects to assess the development of democratic institutions in Spain, Portugal, and Italy. These NSF-supported projects increase knowledge about events of substantial theoretical and policy importance.

Enrichments from Election Studies

The third area of significant accomplishment is the biennial National Election Studies. This long-term project provides the richest and most complete data base on citizen attitudes and voting behavior anywhere in the world. From surveys of representative samples since 1952, these studies have produced high-quality data documenting four major changes in the American electorate: (1) A steady decrease in voter turnout; (2) a marked decrease in citizen attachment to the political parties; (3) a decline in trust in governmental institutions; and, (4) a significant decrease in the competitiveness of congressional elections.

The data of the National Election Studies are uniquely suited for assessing alternative explanations of such changes. They also enrich the understanding of specific Presidential and off-year elections. The National Election Studies are administered as a national resource that is used by scholars at dozens of institutions in the U.S. The systematic scope of the research enterprise has made the field of electoral behavior one of the most scientifically advanced in political science. A very substantial body of knowledge on the role of elections in the U.S. political system now exists.

Establishing a Field of Law and Society

The scientific study of law and law-like systems of rules is one of the most exciting areas of inquiry in the social sciences. In less than two decades, this vital young field has significantly expanded basic knowledge about the legal process, patterns and regularities within it, interaction between the legal system and other social systems, and the role of law in society. The National Science Foundation has played a pivotal role in the development of a theoretically rich and methodologically rigorous science.

The first generation of work in this field--through the 1960's and early 1970's--brought scientific methodologies to the empirical study of law. Conceptually, the research was heavily influenced by a perspective that emphasized the courts, judicial decisions, and the impact of formal legal rules. Structural questions about the efficacy of law and how courts and other legal institutions functioned were prominent. Theory-building reflected a view of law as an independent, self-contained social institution whose role could best be understood by examining the troubled cases it handled (whether crimes or lawsuits) and the failure of its practices to conform to stated objectives (i.e., the so-called gap between law-in-theory and law-in-action).

Important scientific contributions flowed from this early work. Research surveys, in-depth case studies, and analysis of archival data yielded a wealth of information. The role of discretion, the prevalence of bargaining, and the disparities in legal services were carefully described and analyzed. Missing was a sustained quest for explanation and for theoretical understanding of law and legal process in relation to other social phenomena.

Mobilizing the Law

Through the 1970's, with catalytic support from the National Science Foundation, the study of law and legal ordering became more analytic and sophisticated in conceptualization and design. In studying the civil court, for example, important shifts occurred. Instead of focusing only on the court system and organizational structure, scientific inquiry examined dispute processing and the conditions (individual, social, economic, and cultural) that result in the mobilization of law.

The issue of when, why, and how law and other legal forums are mobilized is a core theoretical problem for the social science of law, and thus one that has received substantial NSF support. Through surveys, ethnography, and longitudinal study, this area of research provides new knowledge about the grievance-defining process--how disputes are generated, how they come to be perceived as justifiable claims, how they are processed (formally an informally), and ultimately how they are resolved or fail to be resolved.

Any theory of mobilization must also account for differences in outcomes that occur when people choose to mobilize the law. Preliminary analysis suggests that "repeat players" versus "one-timers" have more success. Comparative and longitudinal research will reveal more about the changing role of the courts and other legal forums as dispute settlers in society. Current work systematically compares disparate units, disaggregates data to see how various sectors of the legal process connect with sectors of the population, develops quantitative indices for comparing legal life across time and space, and illuminates the link between the public forum and other private sectors in dispute processing. The methodological problems are complex. The work is labor-intensive. What is sought is a firm understanding of how, and under what conditions, the law is mobilized.

Pending Issues on Rules of Governance

The agenda for continuing inquiry into the nature of law and law-like systems is large and rich with possibilities for theoretical and practical advancement. Cross-sectional, cross-cultural and longitudinal research is being directed toward social and legal development, social structure and social control, deterrence, legal socialization, legal pluralism, modes of legal decisionmaking, and the social organization of legal representation. Law is no longer treated as a constant in the environment. It connects to and has continuities with other aspects of social life. With NSF support, these linkages are the subject of rigorous research designed to yield an understanding of the dynamics of normative ordering in complex societies.

HOW FIRM ARE THE FOUNDATIONS OF SCIENCE?

From its earliest days, the National Science Foundation has supported research into the historical and philosophical foundations of science itself. These studies illuminate the nature of science as a source of knowledge and explain the various modes in the development of scientific disciplines.

Challenge and Research Response

The period of the 1960's was particularly significant in this area of inquiry. One book, Thomas Kuhn's Structure of Scientific Revolutions introduced concepts and contentions that still reverberate through the halls of the history and philosophy of science. In fact, the book captured large audiences both inside and outside the scientific community by asserting, among other things, that the contents of particular scientific theories are culturally relative pictures of the world, not attempts at true, objective explanation.

Subsequently, historians and philosophers stepped up their analysis of the view that science is a strict, logico-deductive system that builds on prior work in a constant march toward "truth." Philosophers showed that this system simply would not work as a description of scientific explanation. Historians showed that the dominant system of logical analysis did not coincide with historical fact. Furthermore, they documented how many nonrational or even irrational factors affected the growth of science.

The decade of the 1960's ended in a state of intellectual crises concerning an understanding of the nature and development of science. Research in the 1970's began a reconstruction of such basic ideas as the relation of theory and observation, the problem of inference, the nature of scientific explanation, and the interpretation of probability in statistical science.

How Theories Change

Much progress has been made but much is yet to be done. Research supported by the National Science Foundation has made clear that there is no single mode of development for all the sciences. Even within the same science, theory change does not always occur in the same way. The process of change is more likely to be evolutionary rather than revolutionary. When looked at from a distance, a sudden overthrow of one theory by another may seem to have occurred. On closer examination, the revolution is frequently seen to have occurred in small incremental steps.

Studies supported by NSF of the most recent "revolution" in science--that of plate tectonics in geology--support the evolutionary mode even when a Kuhnian revolution seems to have occurred. Plate tectonics successfully predicts new phenomena and appears to overthrow the accepted "steady state" theory. By careful analysis, however, historians and philosophers have found not so much a revolution but a shift in dominance. Plate tectonics is not a new conception. Earlier versions of it had been competing with the "steady state" theory for over one-half a century. Various theoretical explanations developed over this period. During most of this century, the steady state theory held the allegiance of most geologists. With the discoveries from ocean drilling expeditions, however, the allegiance of the majority of geologists shifted to the plate tectonics theory. Can a process of competition over a fifty-year period be called a revolution? Not likely, at least not in the Kuhnian sense.

Other projects supported by NSF have shown that what occurred in plate theory change was not the same as what occurred in another great revolution in our time--that of recombinant DNA. In this case we have no major theory shift but a change "merely" of technique. Yet this change in technique has revolutionized the way conduct of biology as much or more than any recent theory change.

Other Thrusts

Historians and philosophers of science are also directing scholarly inquiry to the great debate in systematics about the mode of operation of evolution--whether it occurs in increments or "great leaps." Similarly, NSF has supported research to follow events in weak interaction in high-energy physics and in nutrino observations of the sun to see if and how "theory change" occurs in these disciplines. Historians are also carefully studying the great "revolutions" of the past--the Newtonian, Darwinian, and Einsteinian revolutions to gain greater insight into those events.

There are multiple paths to theory change, and the forces operating to bring about these changes are much more complex than was assumed in the 1960's. It is on this central issue that studies in the History and Philosophy of Science are concentrating. It is a constructive phase--one that promises to create a knowledge edifice of many facets.

BEHAVIORAL SCIENCES IN THE NATIONAL SCIENCE FOUNDATION

The behavioral sciences at NSF include the classical disciplines of anthropology, linguistics, and psychology. Together with the neurosciences, basic research in these disciplines provides the scientific framework for understanding behavior at various levels from the molecular and cellular to the individual and cultural level. Research in the behavioral sciences attempts to understand human and animal behavior in relation to the biological, cultural, psychological, and socio-environmental factors which affect behavior. Understanding why and under what conditions particular thoughts and actions, i.e. behavior, occur is important to a broad range of human concerns. The Foundation supports cutting-edge, non-clinical research on nervous system function and behavior. The majority of the supported scientists conduct research in the nation's colleges and universities. The nature of recent accomplishments and new opportunities in the behavioral sciences more than justify the continued investment for FY 1982. The following examples are illustrative of research in these fields.

ANTHROPOLOGY

The goal of anthropology is to discern laws or regularities which describe human cultures on a world-wide level. Anthropologists use data from the distant past, recent past, and present to study processes of cultural change as they are revealed over time. Archaeology, physical anthropology and cultural anthropology, are all supported by the NSF program. Using data from the past, archaeologists attempt to understand how cultural patterns developed through time. Physical anthropologists study the broad, multimillion-year sweep of human development and also ways in which biological adaptation presently occurs at individual and population levels. Cultural anthropologists study both primitive and modern cultures in order to discern both similarities and differences among them. The National Science Foundation is the only Federal agency responsbile for the support of basic anthropological research in colleges and universities, and 95% of Federal support comes from NSF. In addition, the NSF fosters the conservation and use of anthropological research collections and the development of new techniques for dating artifacts. Recent progress in many subareas of anthropology have been rapid and further advances during FY 1982 are anticipated.

Human Response to Stress

Response to stress occurs on many levels, i.e., genetic, physiological, and behavioral; in individuals and populations. A major goal of anthropologists is to understand how adaptation to particular stresses is accomplished. Anthropological studies in several parts of the world are examining the human response to such stresses as oxygen-poor, high-altitude environments, scarcity of food and water, and increased population density. To illustrate, discovery of the sophisticated use of multiple resources for water in prehistoric Peru in order to cultivate large areas of land for food provides an excellent example of how study of prehistoric culture can offer practical lessons for modern agricultural planning. In other instances it is possible to trace quantitative changes in a single population over a span of several thousand years, to assess genetic variation and to study adaptation to identified stressors. A variety of new techniques hold great potential for making significant contributions, e.g. bone and tooth analyses to determine diet and nutrition, and longitudinal studies to clarify how living populations respond to stresses associated with culture change and modernization. Responses to these stresses are not well understood, but anthropological approaches represent an opportunity to understand better the consequences of today's rapid change.

The Origins of Humanity

The goal of research on human origins is to understand the processes which have guided the biological and cultural development of our species. The data required to achieve this include not only fossils, but also those archaeological remains that permit reconstruction of past ways of life. For example, use of the scanning electron microscope has revealed wear patterns on stone tools, permitting analysis of how they were used. A significant development over the last decade has been the establishment of research that includes paleoanthropologists, geologists, geophysicists, paleontologists, paleoecologists, etc. Teams of this type permit a focussed search for and rapid evaluation of promising localities for research. They also provide the chronological and environmental expertise to interpret the fossil and cultural remains discovered. Results over the last few years have been impressive.

The ability of archaeologists to draw meaningful conclusions from excavated data is directly related to their ability to date it. The development of radiocarbon dating in the 1950's revolutionized the approach to studying the most recent 35,000 years of human prehistory. Likewise, the impressive gains in our understanding of human origins are due in good part to the development of potassium argon dating and its application to suitable volcanic materials in the East African Rift Valley. Dating research is developing in two directions. First, researchers are trying to extend the limits of existing techniques and to develop new approaches for time intervals where no satisfactory methods exist. Second, research is under way to devise methods for dating materials not now amenable to existing techniques. The most important advance in the last few years has been the development of accelerator techniques for the direct measurement of C_{14}. The direct dating technique will not only reduce the amount of datable material required for analysis, but also extend the range of C^{14} back approximately 100,000 years. The impact of this development on anthropology will be enormous because it will open to detailed examination that period of human prehistory that is marked by the initial appearance of a wide range of cultural phenomena such as art and modern social structure which characterize all known societies today. Another new dating technique of great potential involves thermoluminescent dating of fire-heated rocks. Because humans have used fire for at least half a million years, and since hearth rocks are found in a number of prehistoric sites, this technique could extend both the time range and the kinds of material amenable to dating. A third technique under active development involves analysis or amino acid racemization of bone. The rate of racemization is time dependent. A number of dates have already been obtained by this method but because a number of factors other than time can also affect the rate of racemization, the technique is still in a highly experimental stage.

Cultural Ecology

A wide range of research on how diverse cultures perceive and use natural resources is helping to reveal systematic relations between human food production and the environment. The indigenuous people of the Valley of Mexico have been living and farming there for centuries. Ancient texts have been discovered and deciphered which describe land use practices in the 16th century. The information from these texts and the actual practices of today have been compared in order to determine how soils and productivity of fields have changed over time and to contrast the soil classification systems. Other research is helping to unravel the dynamics of crop evolution in one of the few places in the world, in the Andes Mountains, where traditional agriculture remains intact. Research of this type points up the effects of traditional agricultural practices over long periods of time and allows comparison with modern practices. It should be noted that the introduction of mechanized agriculture with deep plowing into North Africa has resulted not in increased food production but rather accelerated environmental degradation and a northern extension of the Saharan sands.

COGNITIVE SCIENCE

The goal of research in cognitive science is to understand the processes by which human beings learn, think, remember, use language, and solve problems. This rapidly developing area has drawn together the efforts of experimental psychologists, linguists, computer scientists and others to examine these essential human abilities and their development in children.

Representing Knowledge in Memory

Theoretical developments are helping to focus the research that is currently undertaken. As an example, representation theory, which is central to the field, deals with the problem of how an individual's knowledge about the world is acquired, stored, and retrieved. Research on the mental representation of knowledge lies at the core of cognitive science. Current research is examining "visual thinking" as contrasted with "verbal thinking" by attempting to discover how people store visual information in memory and how this information is used in mental processing. The importance of visual thinking has been underscored in the subjective reports of some of the world's greatest scientists. Albert Einstein, for example, claimed to visualize problems and perform "imaginary experiments" when he was formulating his theories.

Cognitive Capability of Children

Cognitive research is characterized by convergence, synthesis and integration across disciplinary lines. Psychologists, linguists, and educational researchers are utilizing several approaches toward understanding such aspects of development as the characterization of cognitive capacities in children, determination of how children acquire language, and the properties of language required for learning. Recent research on the development of cognitive capacities in children has altered our understanding of such capabilities in preschoolers. By designing procedures which are suitable for very young children it has been possible to show that preschoolers have some understanding of numbers, share some of the principles that adults use when reasoning about cause and effect, and understand the difference between animate and inanimate objects objects in the world. Such abilities were thought previously to come much later in the maturation of the child.

Although over twenty years of research on children's learning of English have given us a general understanding of the process, new approaches continue to be important. Current research is focusing on the development of rhythmic control of speech in children acquiring their first language. By carrying out systematic comparisons of the acquisition of a number of languages, scientists will be able to determine the general role of rhythmicity in language learning. Besides its linguistic interest, improved understanding of this developmental process will help deal with a broad class of speech pathologies resulting from imperfectly developed rhythmic control, which are collectively known as stuttering.

Language and the Brain

Study of the anatomical structures and physiological processes of the human brain which are responsible for our ability to use language, a subfield called neurolinguistics, is just now beginning to offer real opportunities for new understanding. It has been known for a long time that minute traces of the brain's activity can be detected by electrodes on the scalp, a technique known as electroencephalography, or EEG. EEG is being used as a technique to gain information about brain activity during perception of various sorts of stimuli. Such research, on event-related potentials, or ERP, has been pursued over the last few years by a few investigators attempting to learn about brain activity related to language use. They have discovered a new ERP, not previously noted, which is called N400. This N400 wave has the interesting and potentially extremely important property of being distinctively related to linguistic processing, which is not true of any of the ERPs which have previously been detected. In particular, N400 arises just when a subject detects a word which is semantically weird in the context of a given sentence, for example the last word of "I take my coffee with cream and dog." Other kinds of "surprising" stimuli yield characteristic other ERP patterns; N400 arises only in this linguistically defined situation. This powerful tool for experimental neurolinguistic research offers a new opportunity.

PSYCHOBIOLOGY

The goal of psychobiological research is to understand the biological basis of behavior in animals. Why is research on the behavior of animals other than human beings important? One reason is that animals generally can be studied more conveniently, understood more thoroughly, and thus provide valuable models for understanding some aspects of human behavior. In addition, research on animals, both in their natural habitats and in captivity, yields results that can be put to use in the management of animal populations, whether in the control of pests, the protection of endangered species, or the humane treatment and productive development of livestock, pets and laboratory animals. Integration between field studies and laboratory approaches in studying the behavior and biology of animals has proven especially valuable.

Animal Orientation

As an illustration, a combination of field and laboratory studies has provided insight into the biological mechanisms controlling key aspects of animal orientation and migration. How are birds, bees, fish, turtles and other animals able to navigate across great distances and reach the same site repeatedly? A newly proposed mechanism for such navigation is the magnetic "sense." Small crystals of magnetite, identified initially in single-celled organisms, have now been found in the heads of homing pigeons and the abdomens of honey bees. The magnetite presumably provides the basis for the animals' abilities to use magnetic field changes in migration and homing. Other sources of navigational information including the sun, stars, and infrasound, have been identified. Now biologists can begin to address the question of how animals integrate such information to produce precise navigational maps.

Animal Communication

Current research is revealing that, whatever modality of communication they use, animals convey much more information--and more specific information--to each other than we previously realized. Odors, for example, can convey information about an individual's species, gender, group membership, social or reproductive status, and even individual identity. Mammalian alarm calls have been found to differ for aerial and terrestrial predators and even for a rapidly or slowly approaching predator, and at least among vervet monkeys the animals hearing the calls for "snake," leopard," and "eagle" have been found to respond differently--and appropriately. These discoveries suggest a degree of symbolic communication previously attributed only to human language. Research on the development of bird song is also revealing many parallels with human language learning, including early undifferentiated voclizations, a period during which adult vocalizations are more readily learned by the young individual than they are later, and the development of local dialects which are culturally transmitted to succeeding generations. Bird songs are also important in the selection of mates, a pivotal process in the evolution of new species. By studying how the behavior of the individual is affected by experience and how the behavior functions in the life of the individual, we are beginning to understand the role of individual experience in the evolutionary process.

Behavioral Endocrinology

One of the most exciting areas of research relating hormones and behavior in recent years has been the unravelling of the developmental origins of sex-typed behaviors. Studies on a variety of avian and mammalian species have linked the occurrence of sex-typed behaviors in adulthood to an individual's endocrine status during a critical period following birth. In mammals, the presence of androgens or estrogens during this critical period predisposes an individual to show species-typical masculine behaviors in adulthood, such as increased aggressiveness, and decreases the probability of feminine behaviors, such as maternal care. Feminine behavior patterns develop in the absence of such hormones. Experimentally reversing the hormonal milieu of males or females during the critical period causes them to develop the behavior patterns of the opposite sex. In some species, mere proximity of females to males in utero has been shown to bias their development in a masculine direction. The effects of circulating hormone levels on brain development have been thought to be the direct basis for these findings since exposure to androgens or estrogens has been shown to influence the growth and activity of nerve cells. However, the results of recent research have added another layer of complexity. Rat mothers consistently groom male infants more than females. If female infants are treated with the odors of male pups, or with male hormones so that they produce male odors, female rats groom both sexes equally. This raises the possibility that some of the effects of early endocrine status may be socially mediated through a complex interaction in which the infant's hormonal status modifies parental behavior, which in turn modifies neural development and ultimately adult behavior. Thus, although our understanding of the developmental origins of sex-typed behaviors has increased tremendously in recent years, much research will be needed before we understand the full complexity of the developmental process.

Mr. Chairman, we'd be happy to respond to any of your questions.

Mr. **Walgren**. Thank you, Dr. Slaughter. We appreciate the testimony very much.

I think perhaps just as a framework for considering the reduction the administration has proposed, we ought to insert in the record at this point a caption of the proposed budget numbers for the biological, behavioral and social sciences, in which in pertinent part, the major reductions appear to be in behavioral and neural sciences, a reduction of 26 percent from the current year's expenditures. Within that category, the neuroscience area would receive an 8-percent increase; the cognitive and behavioral area would receive a 60-percent decrease; and, the anthropological area would receive a 33-percent decrease. And as another major category, the social and economic sciences would receive a 70-percent decrease.

Without objection, that comparison of the present year's expenditures and the future proposals will be made part of the record at this point.

[The information follows:]

Activity	(A) current plan, fiscal year 1981	(B) proposed rescission budget, fiscal year 1981	(C) revised budget, fiscal year 1982	Difference (C-A)	(C-A)/A percent
I. Physiological, cellular, and molecular biology	$77,670,000	$77,670,000	$82,660,000	$+4,990,000	+6.4
II. Environmental biology	41,110,000	41,110,000	43,880,000	+2,770,000	+6.7
III. Behavioral and neural sciences	39,590,000	34,590,000	29,160,000	−10,430,000	−26.3
(Neuroscience)	(16,790,000)	(16,790,000)	(18,600,000)	(+1,370,000	+8.2
(Cognitive and behavioral)	(15,300,000)	(11,800,000)	(6,000,000)	(−9,300,000)	−60.8
(Anthropology)	(7,500,000)	(6,000,000)	(5,000,000)	(−2,500,000)	−33.3
IV. Social and economic sciences	33,620,000	23,620,000	10,100,000	−23,520,000	−70.0
V. Information sciences	6,112,500	6,112,500	6,180,000	+67,500	+1.1
Total	198,102,500	183,102,500	171,980,000	−26,122,500	−13.2

Mr. **Walgren**. The Chair would recognize Mr. Brown.

Mr. **Brown**. Mr. Chairman, I'm sorry that I missed the presentation. I think I understand what was said, however, and I don't know that it would be useful to belabor the posture which the Foundation is constrained to take in this regard. I think the subcommittee will have to make some determinations as to whether anything constructive can be done about the situation.

The thing that has bothered me a little bit about the targeting of reductions in the social and behavioral sciences is the seeming inability of the administration to be aware of the significance, the long-term importance of improving our scientific capabilities in this area, and the direct effect that this can have upon the major national problems that face the country.

I don't know that you have adequate answers to this, but I want to raise the question in case any of you would like to offer any suggestions and, of course, I think the other witnesses that we will have perhaps will have suggestions also.

Would you care to respond to that, Dr. Slaughter, or any of the witnesses?

Dr. SLAUGHTER. Mr. Brown, in our comments we pointed out, as you have surmised correctly, that there are significant ties between the social and behavioral sciences in the areas that we support. And many of the initiatives are important for the country today.

We believe that we are responding at the moment only to a severe financial crisis. That response, we believe, is not motivated by either a lack of understanding of the importance of these areas or by any plan for anything more than a temporary reduction in these areas. We are going to do all we can to continue to stress the importance of these areas to the long-term goals of the administration.

Mr. BROWN. Well, we appreciate that very much and, as we understand the situation, you didn't have any options with regard to where these cuts were taken. I commend you, as a matter of fact, for being able to preserve the core of support for the basic research in the physical sciences, which you've done. I think that insures that we will have a healthy program in these areas, and I think we'll benefit from it.

But would it be asking too much to ask you to comment on the point that if you had been given the same dollar target to reach, but no directives as to the specific cuts that had been made, would you have made them in the same way?

Dr. SLAUGHTER. Particularly in biological, behavorial and social sciences, we would not have wanted to eliminate the critical areas of support that we consider to be an integral part of our fundamental research. Some of those programs have been eliminated in the proposed reductions. Those choices would not have been made.

Mr. BROWN. Thank you very much.

Dr. FRIEDL. May I say a word about that?

Mr. BROWN. Certainly, Dr. Friedl.

Dr. FRIEDL. As, of course, you know, the National Science Board was not involved because of the timing in the various decisions with respect to this. One can say that the last time we were involved—that is, in the preparation of the previous budget—the Board had set its priorities, and the priorities included, as you know, an increase in the behavioral and social sciences budget.

At that time, I think the underlying reason was the assumption that not only is this important for science, but if we are concerned with the national security, as both the Congress, the administration, and the citizens of the United States must of necessity be, and if we are concerned with the human problems of maintaining order, harmony, and a decent quality of life in our society, this research is important for those ends as well. The functioning of our entire defense system depends not only on the Department of Defense, the kind of research that it will do, and the funds that it gets, but also on the human relations in the Armed Forces which are an equally important subject for the maintenance of a good defense system. The behavioral and social science research that has been historically conducted has been of inestimable value to the Armed Forces. Some of that research resulted from what we call basic research in the social and behavioral sciences of the kind that the National Science Foundation has always supported, so that the previous decision on the part of the Board to emphasize the behavioral and social sciences was at least partly motivated by the sense that they were vitally important to this country.

Mr. **Brown**. I very much appreciate that comment and the background it gives as to the attitude of the Science Board.

I think the Board probably is aware that there are at least some elements within the Congress and the administration that feel that the territory within the ken of the social and behavioral sciences is really not science but a function of political leadership, I guess you might say, and that we don't need any help. I very strongly question that, but I'm not the one who's making these decisions right now.

I would make the argument—I hope you will take this constructively—that the social and behavioral sciences need all the help they can get.

I have no further questions.

Dr. **Friedl**. I can not disagree with that one.

Mr. **Walgren**. Thank you, Mr. Brown.

Mr. Weber?

Mr. **Weber**. Thank you, Mr. Chairman.

Dr. Slaughter, we've looked at these numbers quite a bit now, and I wonder if you can just begin by trying to give me a little better idea of what really is within the numbers—specifically or in a more specific way—what types of programs are being eliminated in this area and, more appropriately, what types of programs would be left, and is there a strategy or a rationale within the area of behavioral sciences and social sciences as to what types of activities the Foundation has been pursuing that are less appropriate, and what types are going to receive higher priority in the future? What will be the function of NSF in this area in the future?

Dr. **Slaughter**. Mr. Weber, the future directions are still undefined. We will engage in substantive discussions with the National Science Board during the next several months to assess those future directions. And we will work closely with the social science community, some of whose representatives are here today.

We have a tremendous task ahead of us, and a real challenge to both NSF and the scientific community, to demonstrate the utility and significance of the research efforts we are supporting in the behavioral and social sciences.

Some areas of our program are most critically affected. The support for activities in psychology and sociology is seriously reduced, support for anthropology is all but eliminated, and support for work in linguistics is seriously affected. These are programs where the National Science Foundation provides the lion's share of support to the scientific community.

Mr. **Weber**. In other testimony we've heard here, specifically much of it that compares our situation to that of the Japanese, we've discussed some of the ways in which that nation has channeled its research funds, and they've done it in a very narrow way—and I understand this is the case with the behavioral and social science as well—toward specific productivity-increasing types of projects. Is there any attempt within your budgeting to try and direct funds in a more narrow way in that regard to more specific targets that may have some kind of an economic consequence?

Dr. SLAUGHTER. Our program in economics is vital; the support to researchers doing firstline work in economic fields is singularly important to the issues of innovation and productivity in this country. Reductions in economic research support can have long-term negative consequences.

Dr. FRIEDL. May I say a word about that?

Dr. SLAUGHTER. Yes.

Dr. FRIEDL. As you know, there has been a recent reorganization of the Foundation, and one of the aspects of the reorganization is to put both applied and basic research into the same directorates.

Now, in the behavioral and social sciences, that becomes particularly important because you are going to include applied questions in the general framework instead of putting them into a separate category. That means that the kind of review of the research that will go on will be the same as the review for nonapplied kinds of research.

It will be easier to avoid making a dichotomy between the two and to see where good research can be done. That good research is very likely to come from the social science community these days, partially in terms of policy issues, problems, and concerns of the country as a whole, because the social science community is aware of the possibilities of getting NSF funding for good research in fields that have a more direct relationship to the Nation's general problems than they were able to get before. This funding will be the result of reviews by a group of peers who will be making the kind of judgments that they think are adequate and that will keep the Foundation's grants high in the esteem of the community.

Mr. WEBER. I appreciate that. What about new initiatives within the budget? Are new initiatives essentially curtailed by the budgeting, or do you try and preserve some of those and eliminate the existing program? How do you treat that whole area?

Dr. SLAUGHTER. Some of the new initiatives that appeared in the January budget have been eliminated. However, it is important to realize that we do respond to science-driven proposals. A new initiative may best be described as a proposal for research in a new area submitted to one of our research divisions. Certainly in the social and behavioral sciences, we receive such proposals each year. It is a matter of competition, examination of the quality of the individual proposal, and assessment of funds available to support it. The budget cut does not eliminate the possibility of supporting new research, but it certainly does limit the number of new proposals that can be accepted.

Mr. WEBER. I guess along that line what I'm interested in goes beyond this particular area, but to all the other areas that you've testified to our subcommittee about. In terms of trying to assess a long-term role for the National Science Foundation—and you've assured this subcommittee that you do believe that the administration foresees a long-term role for NSF and views it as the proper function of Government—it would seem that I'm not sure I understand the logic of essentially curtailing most of the new initiatives, unless that's part of a strategy that may essentially let the organization wither on the vine.

If we're looking at a continuing role for NSF with more serious funding constraints, then it doesn't seem to make sense to me that you would curtail new initiatives. You would maybe even have to make some deeper cuts in some of the more traditional areas because you're trying to carve out a new role for yourself, and an ongoing one.

How do you respond to that?

Dr. SLAUGHTER. Mr. Weber, the situation we are facing now for new initiatives is driven largely by the administration's decision to avoid adding to critical problems of the economy. In all of these areas—the physical and life sciences as well—new starts planned for fiscal year 1982 will not be supported, and many are deferred for further analysis. The judgments were made by the administration in its budget-setting process, and we were unable to change the administration's position on that point.

Mr. WEBER. Did you try to change their position?

Dr. SLAUGHTER. Yes, we did.

Dr. LANGENBERG. Mr. Chairman, if I might add a comment. We are talking about two kinds of new initiatives, and perhaps we are confusing them to some extent. First, there are new initiatives proposed to us every day, unsolicited from scientists in one or another of the scientific communities that we support. Second, another kind of new initiative comes from the National Science Board when it establishes a program perhaps to encourage the development of a particular field or area of science. One such development in recent years has been our program in information science and technology; it survives in the revised budget. Another example is in the particular area of the social and economic sciences. A new program had been planned in decision and management sciences, but because of the severe cuts made in that part of the budget, the program does not appear.

Mr. WEBER. I have one final question, and I'm going to ask you again to address the question of priorities, even though I know you've gone over that many times before our subcommittee. But the chairman in his statement made reference to, I think, a pretty legitimate point of view, which is shared by many, that the importance of behavioral and social sciences in the future may be even greater, that we have gone through a period of substantial investment and advancement in physical and biological sciences, and that indeed there may be a reason why the priority of behavioral and social sciences in the future is even greater than in the past. That, of course, is directly contradictory to the direction that the administration has proposed, and I would like you again to respond to that. Do you not share that point of view about the role of social and behavioral sciences in the future?

Dr. SLAUGHTER. I do share it strongly, Mr. Weber. The social and behavioral sciences play a key, and in some cases preeminent, role in some of the critical problems facing the country. The enormous challenge facing the Foundation and the scientific community particularly concerned with the social and behavioral sciences demonstrates your point conclusively. We must strengthen the role of the behavioral and social sciences within the Foundation and strengthen the support to the scientific community in the future.

Mr. WEBER. Without putting words in your mouth about that, it doesn't sound like you're really in accord, then, with the priorities in this budget.

Dr. SLAUGHTER. Under the circumstances and the stringent reductions imposed, the administration posture is supportable and fully understandable. We believe, though, that we will have the opportunity to interact with the administration in the future to bolster the position of the behavioral and social sciences.

Mr. WEBER. I have no further questions, Mr. Chairman. Thank you.

Mr. WALGREN. Thank you, Mr. Weber.

The Chair would like to recognize the presence of his counterpart on the minority side, Mrs. Heckler.

I'm glad you're here. Do you have questions at this point?

Mrs. HECKLER. Not at this point. Thank you, Mr. Chairman.

Mr. WALGREN. Mr. Dymally?

Mr. DYMALLY. Yes, Mr. Chairman, I have a question for Dr. Friedl and Dr. Clark.

Are you receiving as much communication as we are about these cuts from the members of the science community?

Dr. FRIEDL. Yes.

Mr. DYMALLY. That's what I figured. [Laughter.]

Dr. FRIEDL. Clearly.

Mr. DYMALLY. My second question is for Dr. Slaughter.

Once your budget has been passed by the Congress and signed by the President, do you have any administrative flexibility to change priorities at all?

Dr. SLAUGHTER. There is some administrative flexibility, Mr. Dymally. I need to be reminded of the precise percentage——

Dr. CLARK. Ten percent, I think.

Dr. SLAUGHTER. It is 10 percent within the appropriation.

Mr. WALGREN. Thank you, Mr. Dymally.

Mr. DYMALLY. Thank you, Mr. Chairman.

Mr. BROWN. May I make an additional comment here on the relevance of the social sciences as represented in the Japanese society, and I mention this because I had a chance to read a publication recently that really was quite astounding to me. It was a report of the projections of the Japanese technological program for the next 20 years. It was sort of a giant delfian process in which experts from all over the country in both the technologies and in the social sciences were submitting views about what they felt the future held. It turns out to be a fascinating combination of what new technologies could produce and what a rapidly changing sense of values in the Japanese society would demand. It represented an effort to meld these two in an effort to construct a vision of what the markets would be.

We sometimes don't realize it, but markets are generally driven by value structures in society, and I think we have the tendency in this country to feel that the technology drives the market when it's really the value systems coupled with the technologies that drive the market.

This operation, which resulted in a rather extensive publication, represented that melding in a way which I have never seen in a similar fashion in this country. It probably represents one of the reasons, at least, why the Japanese will have a greater command of these markets in 10 or 15 years than we will have in this country. It opened my eyes to some of the problems that we have in this country as I read this, and I wanted to comment on it for the record.

Mr. **Walgren**. Thank you, Mr. Brown.

Comments? Yes?

Dr. **Friedl**. If I may, Mr. Chairman.

Mr. Brown, you have just joined the anthropological community, which makes that kind of statement constantly, and it is a very important part of the research that anthropologists do, so I thank you on our behalf.

Mr. **Walgren**. The Chair recognizes Mrs. Heckler.

Mrs. **Heckler**. Dr. Slaughter, I would like to return to a subject that we discussed at the last session at which you testified, the subject of the budget process, and as I understand it, you were given the opportunity to respond to the suggested or the proposed cuts by the Office of Management and Budget. Is that correct?

Dr. **Slaughter**. Yes.

Mrs. **Heckler**. And you responded—could you tell the committee how you did respond or what your response was?

Dr. **Slaughter**. The proposed reductions were first brought to our attention on February 11, and we responded in several ways.

We were concerned about the elimination of some important new initiatives: The critical problem of the quality of the instrumentation in the research universities, women and minorities in science, and improved science education instruction. We were given an opportunity to suggest some changes that did not affect the overall budget numbers for the Foundation, and we were able to strengthen the program somewhat within the constraints of those dollar figures.

Mrs. **Heckler**. Were you given the opportunity to propose equal reductions but in different areas, areas in which you would exercise your own discretion?

Dr. **Slaughter**. For the most part we were unable to do that, although we suggested such changes. We were pleased, however, that we were able to maintain the strong support of the administration for the physical science and life science programs within the Foundation budget. We believe those are the core areas that must be strong if the Foundation is to do its job.

Mrs. **Heckler**. In terms of the process of negotiation between the Office of Management and Budget and the NSF, the proposed cuts were brought to your attention, I presume, as you say, on this February date. At that point, you were given time in which you could respond, you did respond, suggested changes in their approach?

Dr. **Slaughter**. Yes.

Mrs. **Heckler**. Did the Office of Management and Budget at that point give you the opportunity to make equally deep cuts or cuts of the same quantity but in different program areas? In other words, were you ever given the opportunity to exercise your own discretion, but within the constraints of achieving the same budgetary goal?

Dr. **Slaughter**. No; we were not.

Mrs. **Heckler**. Because that has been the process in other committees and in other areas, the process did involve the opportunity for the head of the department to make suggestions and so forth.

Dr. **Slaughter**. No; we did not.

Mrs. **Heckler**. Not at all?

Dr. **Slaughter**. No.

Mr. **Walgren**. That strikes me as really the most critical factor in this process that NSF has gone through, and it leads to an area I had wanted to try to explore with you. It seems that there is now no way to give any higher priority to the highest of priority or the most valuable efforts that might be made in these areas which were cut when compared to the lowest priority of research in other areas, such as chemistry or something like that, and I noticed, for example, that NSF funds substantially more of the proposals in the hard sciences than they do in the behavioral sciences. My question is: Is there any way to relate the highest priority among the behavioral sciences to the lowest priority that receives funding in any other area?

Dr. **Slaughter**. No.

Mr. **Walgren**. You are now unable to fund even the highest priority in the behavioral sciences, even though you are able to fund the lowest priority in another area, is that correct?

Dr. **Slaughter**. That is correct. It is very difficult to set priorities in the way you suggest, of course, because we are talking about different kinds of disciplines, different kinds of scientific communities, different kinds of needs. We are not able to make that tradeoff.

Mr. **Walgren**. But if you were able to balance the commitment in these areas in a different way, rather than being put in a position of accepting essentially a zeroing out of whole categories, you could make that kind of value judgment, couldn't you?

Dr. **Slaughter**. Yes.

Mr. **Walgren**. And you're not able to, even though we do consider science to be an area of great independence from the political value judgments of the society.

Dr. **Langenberg**. Mr. Chairman, it needs to be said, however, that even in those areas that will remain relatively well funded—areas in the natural sciences—the cutoff point is still high. While the so-called success rate in the natural sciences is typically higher than it has been in the social and economic sciences, it is nevertheless true that we are unable to fund a great many proposals of very high quality.

It is also true that another effect has been operating in those areas for many years: The thresholds are so high that no one who does not feel he or she has a real shot at getting a grant feels it worthwhile to go through the extensive and time-consuming process of creating a proposal.

Mr. **Walgren**. I wanted to ask whether these priorities that are reflected in this budget are inconsistent with the current 5-year outlook that the Foundation has developed in response to the congressional effort to look down the road? Is that correct?

Dr. **Slaughter**. The outlook shows a stronger role for the behavioral and social sciences than this budget reflects.

Mr. **Walgren**. And we're starting on this program immediately with a request for rescission, are we not, in fiscal year 1981?

Dr. **Slaughter**. That is correct.

Mr. Walgren. And what will be the impact of that rescission on the current programs in these areas? There no new startups of any kind, I would imagine, under that rescission?

Dr. Slaughter. I am going to ask Dr. Clark to respond.

Dr. Clark. All right, I'm sorry. Could you repeat it just to make sure I understand it?

Mr. Walgren. Well, as I understand it, there is a corresponding rescission proposed for fiscal year 1981——

Dr. Clark. That is correct.

Mr. Walgren [continuing]. Which would select these areas and essentially deny any further funding, and my question is: What's the impact on the present programs that we are carrying out in this fiscal year?

Dr. Clark. I see. The proposed rescission for the social and economic sciences is $10 million. The amount proposed for the behavioral area is $5 million.

It is my understanding that we are somewhat halfway through the expenditures for this fiscal year. That is, the programs have been obligating funds at the usual rate up to now. There are also commitments on the books from investments of prior years. At the level of the rescission, I believe we will have some flexibility in new grants, but very limited. I expect in the next couple of months funding will be essentially exhausted in these fields.

I can provide you precise information for the record, but activity will be quite curtailed.

Mr. Walgren. The committee would appreciate that.

[The information follows:]

All commitments for fiscal year 1981 funds made in earlier years will be honored. Renegotiation to reduce costs on an individual grant basis will be undertaken. The number of new awards will vary according to the post-rescission balance of the individual program elements. For some programs, such as economics, there will be virtually no balance. Consequently, few it any new awards will be made for the rest of the fiscal year.

Fiscal year 1981 rescission budget	$23,620,000
Obligated from prior years	7,365,087
Obligated from new awards	11,678,776
Balance remaining	4,976,147

The volume of proposal submissions continues to increase and we continue our review and evaluation procedures. We anticipate, however, that we will be able to fund only about 10 percent of the application in fiscal year 1982.

Mr. Walgren. It seems, Dr. Slaughter, that your testimony is a ringing endorsement of the value of the National Science Foundation's effort in this area, and yet we will apparently be confronted with reducing it so completely.

In other areas, we face the problem of when the programs get so small, they don't sufficiently address an area and therefore do not compete for priority funding.

Between the lines in your testimony, I think it's probably fair to say that you would hope that in the future we can do more in this area. Won't we really be prejudiced by the reductions in the present so completely that it will be hard for efforts in this area to compete in the future with priorities, or to establish their priority in the future because we are reducing it down to such a de minimis level?

Dr. SLAUGHTER. I trust that will not occur, Mr. Chairman. We should recognize that we are responding to a severe budgetary situation. We are not responding to an elimination of major areas of our program. By no means do we feel that this budget represents an elimination of the social and behavioral sciences, and we want to put a strong program before you next year. I don't think that the circumstance you mentioned will occur.

Mr. WALGREN. Thank you.

The Chair would recognize Mr. Shamansky.

Mr. SHAMANSKY. Thank you, Mr. Chairman.

I've been concerned about something, and I'll take the opportunity that maybe you can enlighten me. If I remember President Reagan's speech on February 18, he pointed out that he had been advised by some very fine economists in preparing his approach in this message.

Given the fact that economics could be described in these terms here as a soft science, I am a little concerned that the soft sciences seem to be eliminated substantially from the funding. Now, this seems to be sort of a contradiction—to cite economists as backing up or supporting his economic message, which affects the whole country, if not the whole world, and then turn around and make a decision by the administration to eliminate, in effect, these very fine economists because they represent a soft science.

Has this been addressed as to the value of economics within the administration?

Dr. SLAUGHTER. I am sure the issue has been raised, Congressman Shamansky. We have not had an opportunity to talk with the administration about this particular matter, but we plan to do all that we can to articulate the role of economics and support for economic research in innovation and productivity, issues that the President is so rightfully concerned about.

Mr. SHAMANSKY. It would certainly be a great help to me, because I am being asked to support this program presented by the President, yet I'm worried about its integrity now because of the apparent value judgment that economics is not as important as a hard science.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Shamansky.

We would like, as a committee, to submit some questions in writing that perhaps would develop some of these areas more fully, and thank you very much for coming back again to the committee. We appreciate your time, and we hope to see you all soon.

Dr. SLAUGHTER. Thank you.

Mr. WALGREN. The next panel is two outstanding individuals in the area of economics: Dr. Lawrence Klein, Nobel Laureate in Economics in the year 1980, who serves as a professor at the University of Pennsylvania, and Dr. Zvi Griliches, who is chairman of the Department of Economics at Harvard University.

If you two gentlemen would join us, we would welcome you to the committee. We appreciate your coming and giving us your advice and perspective, and I'd like to ask, first, Dr. Klein, if you would like to proceed. Any formal written statement or submission in writing you would like to make would be made part of our record, and you can proceed as you would like. We appreciate your being here.

[A biographical sketch of Dr. Klein follows:]

Dr. Lawrence R. Klein

Dr. Lawrence R. Klein is Benjamin Franklin Professor of Economics and Finance of the University of Pennsylvania. Professor Klein has contributed to Macroeconomic Analysis in "The Keynesian Revolution" (1947) and many research papers. He built statistical models of the U.S. and other economies, beginning in 1946. He published "A Textbook of Econometrics" (1952), "An Introduction to Econometrics" (1962), and several research papers in applied and theoretical econometrics. His first models were published in "Economic Fluctuations in the United States, 1921-41" (1950). He is a past president of the Econometric Society and American Economic Association. He is presently a member of the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society. He is founder and chairman of the Professional Board of Wharton Econometric Forecasting Associates. Dr. Klein was the Nobel Laureate in Economics, 1980.

STATEMENT OF DR. LAWRENCE R. KLEIN, BENJAMIN FRANKLIN PROFESSOR OF ECONOMICS AND FINANCE, UNIVERSITY OF PENNSYLVANIA, AND NOBEL LAUREATE IN ECONOMICS—1980

Dr. Klein. Thank you, Mr. Chairman.

I have submitted a brief statement, and perhaps I'll read it, commenting on parts—it's not very long.

The life blood of any scientific discipline is in research. The ability and facility to carry out research activities on a broad scale and in depth is as much a part of social science as of natural science. Our ability to convey knowledge to successive generations of students depends on our remaining at the frontiers of our respective subjects and in keeping our students in touch with latest developments, best practices and modes of thought.

At a personal level, I find it useful—and even optimal—to teach by the technique of learning while doing. I work regularly with my own students, both undergraduate and postgraduate, in ongoing research activity. They learn research methods in the context of challenging contemporary problems. This method has proved to be extremely valuable but needs funded research activities for its maintenance. To do otherwise and to teach entirely in the classroom according to available textbooks is comparatively sterile and, if practiced on a large scale nationwide, will eventually lead us into professional decay. The richness of materials generated by research activities makes pedagogy all the more interesting, relevant, and productive.

In my own subject, economics, the United States is now preeminent—and I would like to stress that point, that we occupy a leading role in the world activity in economic thinking, and it's very important, I believe, for us to keep it there.

It is mainly through research activity that we have achieved this position, which gives us the opportunity to teach students from the world over, who are apparently drawn here for their schooling. This has enabled our country to influence a network of cultural and intellectual contacts of utmost importance. Any serious interference with this position should be strongly resisted.

Over the years, the support of research in the social sciences has shifted from the large private foundations to the National Science Foundation. True enough, research support is also available from the private business sector and public agencies, but such research is almost always tied to particular tasks under a research contract.

For some social science investigators this works well, for their research may be of a sort that blends well with specific tasks dealing with substantive issues, but for the most part, such research will lack creativity and all the social scientists do not have the knack of working in a contractual mode.

We never know where great new ideas are lurking, how they will be discovered, or when they will appear, but we do know that when free, unfettered research is pursued on a large scale, there will be many new finds. It is much like the present oil and gas search. Widespread activity is bound to turn up an increasing number of productive holes, but there will be many dry holes along the way, and the location or timing of successes will not be known in advance.

As the major private foundations shifted some of their areas of interest, in an understandable approach toward diversification, and as they witnessed the depreciation of their portfolios during the 1970's, the social science community came to rely increasingly on the National Science Foundation as the prime source of support.

In economics, this support has been unencumbered by contractual obligations. It has been of a sort that promotes free thinking and the generation of new ideas, and has gone, to a large extent, to young scholars who do not have extensive resources or alternative connections for research funding. It has been extremely successful in building American advancement in all the social sciences through research activity by younger people who are at the peak of their productivity cycle. They have nowhere else to turn, and it would be a tremendous waste of resources to cut off their research funding.

It is often claimed that social science research has not been useful. On the contrary, not only has American research achieved the leading position on a world scale, but it has also been highly practical in helping with problems of the day.

I personally can speak for that segment of the information industry associated with econometrics. For nearly 40 years, I've been laboring on the development of statistical models of the economy as a whole.

Ideas that were developed in research institutes and in academic institutions grew from very modest beginnings with support from the Rockefeller Foundation, the Carnegie Corporation, the Ford Foundation, and later from the National Science Foundation, to become systems that are now used on a practical basis in private enterprises, banks, international agencies, Federal Government offices, and State and local government offices, in a market that exceeds $100 million annually. It is still a growth sector of the economy.

Fortunately, my associates and I can carry on research without support from the National Science Foundation, but such support was instrumental in getting us to this position, in providing the seed money. Ours is a success story of self-financing, and there will be many more in the future. In the 1940's and 1950's, when my associates and I were wholly dependent on foundation grants, we did not know that we would eventually be supported, as we are today, through the sale of practical services in the information industry, and I am confident that seed money given to many other new research ventures will eventually lead to useful research in the interest of society, but we cannot know in advance which ones will be the successful ones.

Much is said nowadays about the loss of American competitiveness. Our declining rate of growth of productivity, the buildup of large external payments deficits, the loss of world market shares, and the serious depreciation of the dollar all took place in a decade that witnessed a significant cutback in the Federal support of R. & D. and of basic research.

The year 1968 marked the beginning of large real reductions in National Science Foundation and other Federal funding for research as part of the Revenue and Expenditure Controls Act introduced by President Johnson. From that point forward, universities began to experience budget deficits, and the statistics of research support went into decline. For nearly a decade, the real—that is, corrected for inflation—bill for R. & D. support, or the ratio of such support to gross national product, fell. It barely began to recover at the end of the decade.

I would argue that it is not possible to starve the research community for protracted periods of time without seeing the consequences in productivity. I feel convinced that some significant part of our productivity slowdown and general loss of competitiveness is due to the disappointing program of Federal research support of the 1970's. I think this is an important national issue, not only for the cutback in the social sciences but for the cutback in the research establishment in general, and this is a point of time where the American economy needs more than ever before some gains in productivity, and I'm sure they're going to come through the support of basic research.

In a similar way, the productivity of economists will deteriorate if they are now to enter a phase in which research support is drastically reduced. There are many challenging problems looming on the horizon. Let me cite these:

How can we finance social security?

How can we deal with stagflation?

What are the causes of the productivity slowdown?

How can we stabilize the exchange value of the dollar?

What should be the shape of the future world monetary system?

How can we best preserve our exhaustible resources?

I could go on and list problems for many minutes and many pages. These and other perplexing economic problems need careful thinking. Development of special tools or powers of analysis and sound data bases also are needed. Research on such important national problems or methods of dealing with them are typical subjects for awards from the National Science Foundation.

In order to meet these challenging issues of the day, we need a corps of young professional economists who are dedicated to their treatment, and I would argue that a vigorous program of research support from the National Science Foundation is essential to the building up of a young group of professional economists who can deal with these issues.

Budget cutting in the Federal establishment is not at all bad. This may be a time when we should cut back. But we do need stricter fiscal discipline and more efficiency in Government operations. Some level of reduction in the budget of the National Science Foundation could possibly be argued on a persuasive level.

Given a degree of reduction, if that is deemed to be inevitable, then, in the spirit of individual freedom of choice, which is the hallmark of this new administration, there should be a diversified series of cuts, but the decision about where to cut should not be made at a political level. That could easily lead to inefficient and otherwise unsatisfactory kinds of cuts. It is far better to decentralize the decisionmaking process, allowing the scientists on the top governing boards of the NSF to make the decisions about where to cut. The scientists are in a better position to know what is promising and what is not. They should choose where to make reductions of staff and other cutbacks.

The social scientists responsible for the economics program, through the wise counsel of a review board, have shown an ability to make objective and balanced judgment, devoid of political content. Over the years, the National Science Foundation's officers in economics have provided grants over a wide spectrum, supporting all widely accepted doctrines in our subject. They have made awards to proponents of rational expectations, monetarism, fiscal and monetary orthodoxy, as well as to mainstream economics ~~of~~ the analysis of employment determination, effective demand, and productivity trends.

There has been no neglect of microeconomic data samples. Investigation into income distribution, pricing systems, family budgets, business surveys, and other related topics have all received NSF support in the last few years. There is every reason to believe that economics grants from the NSF will continue to be fair, contributory to the resolution of important national problems, and in the fullest interests of the Nation.

Thank you.

Mr. **Walgren**. Thank you, Dr. Klein.

We'll go directly to Dr. Griliches and then have discussion with the panel.

[A biographical sketch of Dr. Griliches follows:]

Dr. Zvi Griliches

Zvi Griliches (Ph. D. University of Chicago, 1957) is the Nathaniel Ropes Professor of Political Economy and Chairman of the Department of Economics, Harvard University. He received the J. B. Clark Medal from the American Economic Association in 1965; he was President of the Econometric Society, 1975; he was elected to the National Academy of Sciences in 1975. He is currently a member of the Executive Committee of the American Economic Association and Director of the Productivity and Technical Change Program of the National Bureau of Economic Research. He is also a member of the Committee of Science Indicators of the Social Science Research Council, the Committee on National Statistics of the National Academy of Sciences, and has been a member of the Panel on Youth, President's Scientific Advisory Committee, the Committee on the Social Sciences in the National Science Foundation (appointed by the National Academy of Sciences), and the Committee on Ability Testing of the National Academy of Sciences.

Mr. Griliches is the author of a number of publications in agricultural economics, econometrics, and the economics of productivity and technological change. Among the latter were: "Hybrid Corn: An Exploration in the Economics of Technological Change," (Econometrica, October 1957); "Research Costs and Social Returns: Hybrid Corn and Related Innovations," (Journal of Political Economy, October 1958); "Research Expenditures, Education, and the Aggregate Agricultural Production Function," (American Economic Review, December 1964); "The Explanation of Productivity Change," (with D. Jorgenson), (Review of Economic Studies, July 1967); Economies of Scale and the Form of the Production Function (with V. Ringstad) 1971; Price Indexes and Quality Change (Harvard University Press, 1971); "Research Expenditures and Growth Accounting," in B. R. Williams (ed.), Science and Technology in Economic Growth, 1973; "Issues in Assessing the Contribution of R&D to Productivity Growth," (The Bell Journal of Economics, 1979); "Returns to Research and Development Expenditures in the Private Sector," in J. W. Kendrick and B. Vaccara (eds.) New Developments in Productivity Measurement, 1980; "R&D and the Productivity Slowdown," (American Economic Review, 1980).

Born September 12, 1930, in Kaunas, Lithuania, Mr. Griliches became a U.S. citizen in 1959.

Mr. Griliches studied at Hebrew University in Jerusalem in 1950–51, and received a B.S. in 1953 with highest honors and an M.S., both in agricultural economics from the University of California at Berkeley in 1954. He received an M.A. in 1955 and a Ph. D. in 1957, both in economics, from the University of Chicago where he was also on the faculty as Professor of Economics until 1969. He lives in Newton, Massachusetts.

STATEMENT OF DR. ZVI GRILICHES, PROFESSOR OF ECONOMICS AND CHAIRMAN OF THE ECONOMICS DEPARTMENT, HARVARD UNIVERSITY

Dr. GRILICHES. Thank you.

I have also a written statement. I will go over parts of it and skip others to save on time.

I shall try to make the following five points:

One, the proposed differential deep cuts in the budget of the Economic and Social Sciences Directorate of NSF are both unjust and unwise. To support this position I shall argue that:

Two, economic research has made and can make important and valuable contributions to the understanding of the world we live in and to our ability to influence events for the better.

Three, that NSF is the major source of financial support of fundamental—both basic and applied—disinterested research in economics.

Four, that cuts of the suggested magnitude will cripple economic research for years to come, especially substantitive empirical research on important policy issues.

And, five, that the motivation for these specifically targeted cuts appears to be based on vindictiveness, arrogance, and ignorance. Wise social policy would not cut itself off from self-knowledge.

The proposed cuts are drastic and unjust. The Economics and Social Science Directorate has been told to absorb a 25-percent cut immediately, this fiscal year. With most of the money appropriated already spent or in the pipeline, this effectively shuts down all activity until further notice.

For fiscal year 1982 the budget has been cut by 75 percent, eliminating almost all current and planned programs. At the same time, there has been no real cut in the rest of NSF activities, except for science education.

If the NSF budget is to be cut at all, which is debatable, it should be an across-the-board cut or, alternatively, the National Science Board should be given the authority to allocate it. There is no good reason for targeting it entirely on the social and behavioral sciences. No evidence has been presented that the best economic research projects are significantly less valuable scientifically and socially than the marginal projects in biology, mathematics, or physics. If there is any evidence on this topic, it goes the other way.

When our National Academy of Sciences committee, which I served on in the mid-1970's, the Simon committee, reviewed the work of NSF in the social sciences in the mid-1970's, we found that it was funding approximately 60 percent of all submitted projects in the physical and biological sciences, but only 30 percent in the social sciences. The social science budgets were always smaller and the selection on project quality more rigorous.

The social sciences are not unimportant or soft. The study of man and his interaction with his environment is as fundamental, difficult, and rewarding as the study of matter or of man as a biological machine.

Economics is a hard science in the sense that it imposes scientific standards of logic on arguments and strives for rigorous interpretation of statistical evidence. In this, it differs little, if at all, from other sciences. The difficulties that economics faces arise from the complexity of human behavior and from the inability to apply the experimental method to most of its problems. That makes the task harder and good answers scarcer, but no less valuable.

The potential value of economic research can be illustrated by a simple macroeconomic example. If all macroeconomic research, past, present, and future, resulted in a reduction of unemployment of only 1 percentage point for only 1 year, it would be worth to the economy about $70 billion. The original fiscal year 1982 budget for all NSF-supported economic research, macro and micro, basic and applied, was $17 million. Even if one cumulates all past NSF economic support, one will not get a benefit cost ratio below 100.

Similarly, recent research shows that efficiency losses arising from our current tax system may be on the order of 20 percent of its receipts, which yields an estimate of about $120 billion deadweight loss annually. If research could find a way of reducing this loss by 10 percent, it would yield a social return of $12 billion per year, enough to pay for the NSF economics budget many times over.

Or consider our lagging productivity growth problems; though there is much disagreement about its causes, most informal observers would agree that the problem is behavioral, not technological. The issue is not that somehow we have less technology or less access to frontier technology, but rather that we have had difficulty in adopting and using it effectively.

I will not go on to list various projects and achievements of economics, which are given in my prepared statement, but I want to address one particular point, and that is the value of research, and NSF-supported research in particular arises not solely from the particular successes of a particular research project. Much of research is really devoted to the maintenance and expansion of our scientific base. By asking questions carefully, by restudying all answers and reviewing the quality of the data, we engage in maintaining our knowledge and in training a new generation of analysts.

The research establishment breathes life into university training and graduate programs, which in turn produce most of the high-quality economists staffing Government departments, congressional committees, and business corporations. Not only are research programs at stake, but so is also the vitality of the associated university graduate programs.

The National Science Foundation is the only significant source of disinterested research money in economics. Both the Rockefeller and Ford Foundations moved out of supporting economic research some time ago. Agency support tends to be very topic specific, directed to today's fashion, and with many strings attached. Imagine the Social Security Administration funding research which shows its negative effect on the U.S. saving rate.

Much of the other research money available in economics comes from corporate sources or specific foundations and tends to support particular views or foster particular specific lines of research. The NSF is one of the very few sources of research money whose allocation is made almost entirely on the basis of scientific merit.

The disappearance of such support will affect quantitative-empirical work disproportionately. Abstract theoretical work may go on without much public support. Current economic forecasting may continue in the private sector, based on D.R.I. work and Chase Econometrics and similar firms, but longer term research into the quality and underlying basis of such endeavors will suffer greatly.

Much of the current exciting work on the response of individuals to various tax, subsidy, and retirement schemes based on extensive analysis of newly collected survey data will just not get done—will not get finished, much less get started. Similarly, analysis of the impact of changes in energy prices on the relative competitiveness of different industries which require serious large-scale data analyses will not get done.

Econometric research, by which I mean detailed statistical and economic analysis of large data sets, cannot be done on a shoestring, after hours, on a pocket calculator. Careful data checking alone requires a significant level of man-hours, and the processing of large bodies of data involves the indispensable services of programers and computer time. None of it is very expensive, but it does cost money.

For example, the Census Bureau is putting together currently under my direction and with NSF financing the data it has collected in annual surveys on R. & D. expenditures—from company R. & D. expenditures. These data are collected annually but have never been put together so that one can follow the expenditures over time of individual firms. What we're trying to do is to format them so that one can follow the futures of individual companies and see how and when R. & D. paid off. This involves a data base of about 1,000 companies for 20 years with 10 to 50 variables measured for each firm in each year. To match, clean, access, and analyze such data is a major task. It involves processing over half a million of different numbers.

This work is worth doing, I think—I have been spending a good number of years on it—but it cannot be done without significant computer and research resources. It is this kind of work that won't get done if these cuts are sustained.

I turn now to the motivation for the proposed cuts. As I noted above, no reasoned case has been made that social science research is either valueless or of lower scientific quality than other NSF-supported research, nor did Dr. Slaughter's admirable statement present even an iota of evidence that the social sciences deserve lower priority.

We all know that these are not NSF's or the National Science Board's considered priority judgments. This may be the OMB's judgment, but they, too, couldn't have really been based on any serious scientific analysis. I can therefore attribute the motivation for such selective cuts only to vindictiveness, ignorance, and arrogance.

Vindictiveness—because many of the more extreme new economic proposals have found little support among established scientists. Because they have not flocked to support them, they are perceived as being captives of liberal left-wing ideologues. Ignorance, because this is just not so. It is ironic and sad that whoever came up with these cuts does not even recognize that most of the recent conservative ideas in economics—the importance of rational expectations and the impotency of conventional macroeconomic policy, the disincentive effects of various income-support programs, the magnitude of the regulatory burden, and the arguments for deregulation—all originated in or were provided with quantitative backing by NSF supported studies. And, arrogance, in the sense that those suggesting these cuts do not seem to want to know what good economic policy can or should be. They do not need more research; they know the answers. The country is embarking on one of the largest macroeconomic policy experiments in our history with very little research support for it, and they do not even want to know how to measure its effect, how it is going, and what its consequences might be.

I am not pleading for myself. I am senior enough and working on a hot enough topic—R. & D. and productivity—to survive such cuts relatively unscathed. What I'm afraid of, and what I would like you to stop, is the dismantling of the whole economic research enterprise.

What will be hurt is not only the current research endeavor, but also our future ability to understand and analyze the economy and its problems quantitatively. Moreover, we may lose a whole generation of economic analysts.

Where will the expertise come from when you will need it in the future?

Thank you.

[The prepared statement of Dr. Griliches follows:]

Statement before the Science, Research and Technology Subcommittee of
The Committee on Science and Technology of the U.S. House of Representatives.

My name is Zvi Griliches. I am Professor of Economics and Chairman of the Economics Department at Harvard University. I am a member of the National Academy of Sciences, member of the Executive Committee of the American Economics Association, and past President of the Econometric Society. My primary fields of expertise are agricultural economics, econometrics, and the economics of research, innovation, and technological change. I am familiar with the operations of the Social and Economic Sciences Directorate of the National Science Foundation, both through past service on the Economics Panel of the NSF and membership in the NAS panel (the Simon Committee) which evaluated the Behavioral Sciences Division of the NSF in the mid 70's. My comments are my own and do not represent the opinions or position of any of the above mentioned organizations.

I shall try to make the following points:

1. The proposed differential deep cuts in the budget of the Economic and Social Sciences Directorate of the NSF are both unjust and unwise. To support this position, I shall argue that
2. Economic research has made and can make important and valuable contributions to the understanding of the world we live in and to our ability to influence events for the better,
3. That NSF is the major source of financial support of fundamental (both basic and applied) "disinterested" research in economics,

4. That cuts of the suggested magnitude will cripple economic research for years to come, especially substantive empirical research on important policy issues, and
5. That the motivation for such cuts appears to be based on vindictiveness, ignorance, and arrogance. Wise social policy would not cut itself off from self-knowledge.

I shall now elaborate on these points.

The proposed cuts are drastic and unjust. They use a meat cleaver, not a scalpel. The Economics and Social Science Directorate has been told to absorb a 25 percent cut immediately, this fiscal year. With most of the money originally appropriated already spent, or in the pipeline, this has effectively shut down all activity until further notice. For the coming budget year, Fiscal Year 1982, the budget has been cut by 75 percent, eliminating almost all current and planned programs. At the same time, there has been *no* real cut in the rest of NSF activities, except for Science Education. If the NSF's budget is to be cut, which is debatable, it should be *an* across-the-board one, or, alternatively, the National Science Board should be given the authority to allocate it. There is no reason for targeting it entirely and solely on Social and Behavioral Sciences. No evidence has been presented that the *best* economic research projects are significantly less valuable scientifically and socially than the *marginal* projects in biology, mathematics or physics. If there is any evidence on this topic, it goes the other way. When our NAS committee reviewed the work of NSF in the mid 70's we found that it was funding approximately 60 percent of all *submitted* projects in the physical sciences, but only 30 percent in the social sciences. The social sciences budgets were always smaller and the selection on project quality more rigorous.

The social sciences are not unimportant or "soft." The study of Man and his interaction with others and with his environment is as fundamental, difficult, and rewarding as the study of matter, or of Man as a biological machine. Economics is a "hard" science, in the sense that it tries to develop logically consistent ideas about human behavior and interaction, work out carefully their implications, collect, observe, and interpret quantitative data about such behavior, and confront various theories and interpretations with the observed facts, with a resultant revision in the original ideas and a search for new knowledge to resolve the remaining uncertainties and provide answers to new questions. Throughout this work scientific standards of logic and interpretation of statistical evidence are imposed and applied. In this, it differs little, if at all, from other sciences. The difficulties that economics faces arise from the complexity of human behavior and from the inability to apply the experimental method to most of its problems. That makes the task harder and good answers scarcer, but no less valuable.

The potential value of economic research can be illustrated by a simple macro-economic example: If all macro-economic research resulted in a reduction of unemployment of only one percentage point for only one year, it would be worth about $70 billion. The original FY '82 budget for all NSF supported economic research, macro and micro, basic, and applied, was $17 million. Even if one cumulates all past NSF economic support, one will not get a benefit cost ratio below 100. Similarly, recent research shows that efficiency losses arising from our current tax system may be on the order of 20 percent of its receipts, which yield an estimate of about $120 billion deadweight loss annually. If research could find a way of reducing this loss by 10 percent, it would yield a social return of $12 billion per year, enough to pay for the NSF economics budget many times over.

Most of the NSF supported work is more prosaic and it may be hard to calculate its explicit contributions. Nevertheless, much of it has been of very high scientific quality and has resulted in important insights and policy impacts. My own work (which I know best) has been largely in the area of technological change. It included the first calculation of the rate of return to research, an investigation of the determinants of the rate of technological diffusion, the development of methods to adjust official price indexes for quality improvements in both.producer and consumer durable equipment, the estimation of the contribution of economies of scale and improved educational levels of the labor force to productivity growth, and other related topics. In recent years, I have been engaged in a large scale, NSF supported, study of who invests in R&D and what they and the economy got out of it.

NSF has supported similar work on technological change and returns to innovation by Mansfield (Carnegie-Mellon and Penn), Nelson (Yale), and Scherer (Northwestern) . It supported the work of McFadden (Berkeley and MIT) on sources of productivity growth in the electrical generating industry and on the measurement of the costs and returns of public transport subsidies; the work of Lucas (Carnegie-Mellon and Chicago) on the determinants of investment, the importance of "rational expectations," and the impact of policy actions on the business cycle; the work of Jorgenson (Berkeley and Harvard) on the determinants of investment and the impact of the rise in energy prices on the demand for capital goods; the work of Klein and Griffin (Penn) on the productivity of the steel industry; the work of Feldstein (Harvard) on the impact of Social Security and other taxes on saving and investment in the U.S.

economy; the work of Hall (MIT and Stanford) and Feldstein on the measurement of unemployment and the impact of unemployment compensation on it; the work of Dornbusch (MIT) on the impact of the energy crisis-induced international monetary flows on our balance of payments; the work of Arrow (Harvard and Stanford) on the definition of social risk from nuclear reactors, and much more.

NSF has also provided substantial funding for projects that have enabled others, especially those working on microeconomic problems, to conduct their research. Perhaps the best example of this kind of a cross-cutting project which would not be supported by an individual line agency is the continuing Panel Study of Income Dynamics, conducted by James Morgan at the University of Michigan. It has followed 5000 families for 14 years, yielding the only general longitudinal U.S. data base. These data were used by Hamermesh (Michigan State University) in research funded by the DOL and SSA to analyze whether and to what extent unemployment insurance induces married women to enter the labor market, and to measure the extent to which higher payroll taxes for CASDHI are reflected in reduced wage rates. Answers to this latter question are essential to evaluating the potential inflationary impact of such taxes, and this work was used by the CBO and the Council of Economic Advisors in policy discussion in 1979.

Another example indicates the uses of "esoteric" theory. Economics is about the allocation of scarce resources. The most basic result of economic theory states that under certain conditions a competitive market will result in an efficient allocation of resources. Society uses many mechanisms other than competitive markets to allocate scarce resources. Examples are auctions, committees, and elections. Economic theorists, supported by the NSF, have been trying to understand how these various processes work, when they work efficiently and when they work badly. While the research into the properties of various allocation mechanisms has been some of the most abstract which the NSF has supported, it has also been some of the most applicable. This research had led fairly directly to proposals (some of which have been implemented) for changing the rules by which offshore oil leases are auctioned, the techniques by which public television stations choose their programs and the procedures by which landing rights are allocated at such crowded airports as National and O'Hare (R. Wilson, Milgrom, Plott, V. Smith).

NSF has also supported some shoddy and useless projects. But one cannot pick winners all the time. A research support program must be prepared to take risks and to fail occasionally.

Moreover, even work that does not result in scientific breakthroughs makes an important contribution. Much of "research" is really devoted to the maintainence and expansion of our scientific base. By asking questions carefully, by restuding all answers and reviewing the quality of the data, we engage in maintaining our knowledge and in training a new generation of analysts. The research establishment breathes life into university training and graduate programs which in turn produce most of the high quality economists staffing government departments, congressional committees, and business corporations. Not only are research programs at stake but so is also the vitality of the associated university graduate programs.

The National Science Foundation is the only significant source of "disinterested" research money in economics. Both the Rockefeller and Ford Foundations moved out of supporting economic research some time ago. Agency support (Department of Labor, Energy, etc.) tends to be very topic specific, directed to today's fashion, and with many strings attached. (Imagine the Social Security Administration funding research which shows its negative effects on the U.S. saving rate!) Much of other research money available in economics comes from corporate sources or specific foundations and tends to support particular views or foster particular specific lines of research. The NSF is one of the very few sources of research money whose allocation is made almost entirely on the basis of scientific merit.

The disappearance of such support will affect quantitative-empirical work disproportionately. Abstract theoretical work may go on without much public support (it does not require great resources). Current economic forecasting may continue in the private sector (based on DRI, Chase Econometrics, and similar firms), but longer term research into the quality and underlying basis of such endeavours will suffer greatly. Much of the current exciting work on the response of individuals to various tax, subsidy, and retirement schemes, based on extensive analysis of new collected survy data will just not get done (will not get finished much less get started). Similarly, analyses of the impact of changes in energy prices on the relative competitiveness of different industries which require serious large-scale data analyses, will not get done. Econometric research, by which I mean, detailed statistical and economic analysis of large data sets, cannot be done on a shoestring, after hours, on a pocket calculator. Careful data checking alone requires a significant level of manhours and the processing of large bodies of data involves the indispensible services of programmers and computer time. None of it is very expensive (an average NSF economics research project was funded at a level of about $60,000 per year, of which one third went to university overhead) but it does cost money.

I turn now to the motivation for the proposed cuts. As I noted above, no reasoned case has been made that social science research is either valueless or of lower scientific quality than other NSF supported research. I can, therefore, attribute the motivation for such selective cuts only to vindictiveness, ignorance and arrogance: Vindictiveness, because many of the more extreme new economic proposals have found little support among established scientists. Because they have not flocked to support them, they are perceived as being captives of liberal left-wing ideologues; Ignorance, because this is just not so. It is ironic and sad that whoever came up with these cuts does not even recognize that most of the recent "conservative" ideas in economics -- the importance of "rational expectations" and the impotency of conventional macro-economic policy, the disincentive effects of various income-support programs, the magnitude of the regulatory burden, and the arguments for deregulation -- all originated in, or were provided with quantitative backing by NSF supported studies; And arrogance, in the sense that those suggesting these cuts do not seem to want to know what good economic policy can or should be. They do not need more research, they know the answers. The country is embarking on one of the largest macro-economic policy experiments in our history, with very little research support for it, and they do not even want to know how to measure its effect, how it is doing, and what its consequences might be!

I am not pleading for myself. I am senior enough and working on a "hot" enough topic (R&D and productivity) to survive such cuts relatively unscathed. Nor am I pleading on behalf of the Harvard Economics Department (we will manage). What I am afraid of, and what I would like you to stop, is the dismantling of the whole economic research enterprise. What will be hurt is not only the current research endeavour but also our future ability to understand and analyze the economy and its problems quantitatively. Moreover, we may lose a whole generation of economic analysts. Where will the expertise come from when you will need it in the future?

Mr. WALGREN. Thank you, Dr. Griliches.

The Chair would recognize Mr. Brown.

Mr. BROWN. Mr. Chairman, I don't think I have any questions. I want to thank both of the witnesses for very strong and, to me at least, effective statements that provide a very good basis for trying to rectify this proposed action on the part of the administration. I think the fact that you gentlemen have appeared here and have the eminent status you have in the profession is eloquent testimony to the error of the policy decisions that are reflected here, and I do appreciate your coming.

I wish you were political scientists and could advise us on the political strategy necessary to correct this problem, and it will not be corrected when the economic fallacies, if any—and I'm not prejudging this administration—show up in actual effects in the economy. That will not be blamed on faulty economics; it will be blamed on faulty politicians in the Congress who didn't give enough support to it, or some other abstruse reason of that sort.

But I am grateful for your testimony.

Mr. WALGREN. Thank you, Mr. Brown.

Mrs. Heckler?

Mrs. HECKLER. Well, I'd like to say that I, too, enjoyed the testimony very much.

Obviously, Dr. Griliches, you're not overwhelmed by a fear of making an outspoken remark, and I've very rarely heard anything quite as clear and emotional from a scientist. Both statements, I think, make their points very well, and valid points, indeed.

Nonetheless, with economists of such stature, I cannot resist going beyond the scope of inquiry technically allotted to this subcommittee, and I wonder if each of you would give me your analysis and evaluation of, first of all, the Kemp-Roth tax proposal, and, second, the accelerated depreciation and its ramifications in terms of productivity. Obviously, economic research is important in terms of productivity, but are the expectations and assumptions contained in both of these proposals reasonable, and are they going to succeed, or are they likely to succeed? Dr. Klein?

Dr. KLEIN. Well, one could make a good case for a tax cut now, and that case has been made for the last 6 months or so. I think to lock oneself in—lock the Nation into 3 successive years is going much too far, in the sense that we want to see how the first year works out before you commit yourself for the next 3, or the next 2 to round out 3.

And the Kemp-Roth proposal has merit in the sense of redressing for some of the inflationary impact on individual spending and taxing burdens.

But I very much feel that we've been ducking the issue in this country of tilting the balance in favor of tax cuts that support productivity, and I think that it is a tested and well-documented idea that either accelerated depreciation or investment tax credits or other kinds of investment stimuli would do some good. That has some merit, and I think the Kemp-Roth bill, mixed with the present accelerated depreciation, doesn't give us quite the right balance, and we probably need to go more in the direction of supporting tax cuts that will enhance investment and, hopefully, enhance productivity. And whether it enhances productivity or not depends on the outcome of Dr. Griliches' and similar investigation on what is the link between capital formation and productivity. We aren't so sure about that, but we are fairly sure that accelerated depreciation would contribute markedly to private capital formation.

Now, the Kemp-Roth cuts are useful and in a proper direction, but they should be cut in the context of a total economic package. And I wouldn't want to say they're wrong in themselves, but they're not going to do much on their own for productivity. And the one argument that is being put forward—that they will enhance productivity by enhancing worker incentives—is very dubious, has not come before the professional societies for careful documentation and tests, and you cannot defy the principles of economics in setting economic policy and simply wish that some results are going to work out. You must test them, run through professional opinion and then advocate.

Mrs. **Heckler**. Dr. Klein, do you feel that the size of the tax cut should be related to the scope of the budget deficit and the budgetary cuts?

Dr. **Klein**. Well, not necessarily. I think the link between the deficit and inflation is very poorly understood and, in fact, there is very little direct link.

The argument for cutting spending is quite a different argument, and that is to cut back the activity of the public sector relative to the private sector. The problem about the deficit that is associated with the expenditure cuts, matching the tax cuts, is a problem of the Federal Government's financing the deficit, entering the bond market, bidding up rates, and having an impact back on capital formation. And there is a point in not wanting to increase the deficit for that reason at the present time, because we do want to get capital formation going.

Mrs. **Heckler**. Dr. Griliches?

Dr. **Griliches**. Well, I defer to Dr. Klein on the macroeconomic side. Each one of these policies has some merit and is photovoltaic. One can make an argument for them but one shouldn't expect miracles, and I think that they sort of—there is no particular reason to tie them together with one ribbon into one package.

I think that, given the inflation and no indexation, we have had a significant creep in the brackets, and thus there is some argument for a tax cut, which would just restore the original progressiveness of the tax structure.

I think there is an argument for doing something for investment, particularly because taxes do not recognize inflation. They do not allow for a decent recovery of capital, and I would have also proposed some relief. But I would have thought of something more along the lines of the Auerbach/Jorgenson proposal. But that's a secondary consideration.

I don't see any big supply effects coming out of the income tax cuts, though accelerated depreciation should improve capital formation.

But there is a very big work tax implied in the social security taxes, and there is a very large wedge between what an individual gets when he goes out to work and what an employer has to pay when he hires that individual. Our economy is stuck in a situation where, roughly speaking, people are willing to work at $4 an hour, but employers are not willing to hire them unless their work is worth $8 an hour, and that creates a rather serious distortion in the operation of our economy.

I think that each one of these proposals has some merit and could be fine tuned and could be an improvement. They are not going to give us miracles, nor will they work very fast. Having an effect on productivity takes a long time. It takes time to achieve technological breakthroughs, to develop them, so that they can be actually used, and then it takes time for the economy to absorb them.

I think one of the negative things that affects investment in R. & D. and investment in capital is the overall feeling of uncertainty about the future, uncertainty about what the Government will do, where the economy will go. It's a kind of chicken-and-egg problem, or "Catch-22". If we had more hope in ourselves and in the future, I think people would actually invest and do more.

Mrs. **Heckler**. Of course, there has been very little economic evidence upon which to base hope that we can deal with the problem of inflation, which is one of the reasons, I would assume, that we have such a low level of confidence in ourselves as a society in dealing with this.

What I wondered, apart from the question of the wisdom of the specific cuts in the NSF budget, do you subscribe to the belief that very substantial budget cuts are desirable in terms of Federal spending at this particular point?

Dr. **Griliches**. The Federal budget is so large, it has so many barnacles on it, and it's so difficult to do something about each one of them one at a time so that I have some sympathy for a really drastic approach, sort of shaking things up and trying to do something unthinkable, because otherwise there is a tendency to drift and to acquire new commitments. But I think that's kind of a political science judgment, not an economics judgment. I don't think there is a strong economic theoretical argument that we are going downhill in a great hurry just because the budget has grown—just because it will not go down by 5 percent or will go up by 8 percent next year.

A large part of the budget is a variety of transfers, that's really the biggest part, and it is there that one should reconsider the variety of programs that have been built in. Some of the stuff is not supportable in the long run. We keep closing our eyes off and pretending that it's not going to happen. For example, we've got really to face up to the possibility that the social security system as it is will just blow up. Now, we can say, "Well, we won't be around when it blows up, so why bother about it now?" but I think that's one of the things that one has to face.

But my feeling is that a lot of the budget cuts have not been really thought through that well. They sort of hit wherever the fancy hits, what some particular people didn't like, think is expendable, or think is kind of luxurious. They lump together whatever it is—symphony orchestras and museums and economics and sociologists and school lunch programs and what not—and cut it all.

I think there is a case to be made for one or even many of these reductions, but if there is, it should be made on its own merits.

Mrs. HECKLER. Entirely desirable, but difficult within the political context of the world in which we live.

Dr. GRILICHES. Right.

Mr. WALGREN. Thank you, Mrs. Heckler.

Mr. Gregg?

Mr. GREGG. Thank you, Mr. Chairman.

The question of whether or not the cuts should be made, Dr. Griliches—I just don't understand this characterization of vindictiveness and ignorance and arrogance. It seems to me that that doesn't give us any substantive input on why the cuts are being made or your reaction to them. Those seem to be rather emotional words that don't get into substance, and I do not agree with some of my counterparts on this committee; I find those words to be sort of an affront to our own capabilities and knowledge as a committee. We're up here trying to evaluate cuts in various areas, and you come in here and use terms like that and, as a matter of comment, I say that I find them offensive.

On a more specific area, I would ask Dr. Klein: Your sense is that the failure of—or the deficit spending which we've seen over the last few years is not tied—or does not have any effect on inflation? Is that your position?

Dr. KLEIN. Well, it doesn't have a clear effect—the relationship between inflation and the deficit is not clear or understood. It is a matter of how the deficit is financed, for one thing. The deficit may be monetized and it may not be. And, in addition, much of the inflation that we have had has been due to disturbances in the world economy that are completely outside the purview of our control or the American scene, as such. They have been the oil problems, the food problems, and the end of the Bretton Woods era and the depreciation and devaluation of the dollar. Those have been very important factors in contributing to the inflation at the same time that the budget went into serious deficit.

There were periods in recent years when the budget has been in balance. The budget was in balance at the beginning of the decade of the 1970's and we still had inflationary pressure. I think there are some very deep-rooted reasons for the inflation that we've had and they should not be traced specifically to the budget imbalance.

Mr. GREGG. Well, then, following that logic forward, looking at an $80 billion deficit in 1982—$60 to $80 billion—you find no problems with that sort of budget deficit?

Dr. KLEIN. No; I don't want to see that large a deficit. I simply say we don't know the relation between the deficit and inflation. But on quite different kinds of grounds, I would say yes, we should avoid that kind of deficit.

Mr. GREGG. Well, if we're going to avoid that kind of deficit, I would submit to you that we're going to have to make cuts in the Federal spending, as projected into those years, isn't that correct?

Dr. KLEIN. That may be one of the things.

Mr. GREGG. Or increase taxation; that would be another alternative.

Dr. KLEIN. Well, as I think before 1980, before 1979 and 1980, the budget deficit was falling year by year. It was falling partly as a result of inflation, but it was falling. And the thing that unsettled the budget and threw the economy into very serious deficit was the recession. And one might say to avoid a recession is a very good way of avoiding a budget deficit, because the costs of recession for the budget are enormous.

Mr. **Gregg**. Well, if we're going to—let's assume we're going to have to make some cuts in the budget going into——

Dr. **Klein**. I think that's a very arguable point, a reasonable point; there should be some cuts, yes.

Mr. **Gregg**. And those cuts are going to have to be made in the political marketplace; I think you can accept that fact.

Dr. **Klein**. Right; yes.

Mr. **Gregg**. It would seem to me that there is a logical argument that the political marketplace requires hard decisions in making those cuts.

Dr. **Klein**. Yes.

Mr. **Gregg**. And that a hard decision has been made that your area of business is going to be one of the areas impacted by the cuts.

Dr. **Klein**. Well, I appreciate that. I think I said in my testimony, yes, maybe we have to suffer a cut, maybe we have to have some belt tightening, maybe the Federal establishment has become too large in dollar terms; but, then, why not make the cuts in a way that we would decentralize the decisionmaking? That is to say, if the National Science Foundation is to bear some of the burden of the cut, then why not let the Science Board, or why not let the officers of the National Science Foundation, decide which part should be cut back and which parts should not be cut back, or the relative sizes of cutbacks in different parts? That would seem to be much more efficient than targeting the cuts to specific areas.

Mr. **Gregg**. Well, are you telling us that if after the testimony of the National Science Foundation leadership before this committee, and after this committee sort of adjudicates the matter, we agree that the cut has to be made in the National Science Foundation and we come to the conclusion after that input from the National Science Foundation that the proper place to make the cuts is your area of expertise, your area of interest, that you're going to accept those cuts?

Dr. **Klein**. Well, I mean, we have no recourse except to accept them, but I think I would certainly protest them.

Mr. **Gregg**. Well, we will have gone through the system that you're requesting.

Dr. **Klein**. Yes; oh, yes, if that is the final decision—it seems to me to be a misguided set of priorities, but if it works out that way, yes; that is, if a scientific review process decided on that, then I would have to accept it, yes.

Mr. **Gregg**. Well, I perceive that as why we're pursuing these hearings, quite honestly, is that the cuts are going to be made and we're trying to evaluate the allocation of them.

Dr. **Klein**. I think the whole issue is one of priorities on the total budget, and certainly within the science budget.

Mr. **Gregg**. Thank you.

Yes? Go ahead, Doctor.

Dr. **Griliches**. I just wanted to add that I want to apologize if you found some of my language offensive. The reason I said it a little bit loudly is that as far as I could see, no such argument that you're suggesting has in fact been made.

If after some serious review we have had, you know, a decision that in fact these areas by and large are second rate and other areas are more important, and we had a discussion about it, I may not agree with it, but at least I would have understood somehow the process.

I don't think that these cuts have been discussed with or approved by a large fraction of Republican community or even within the administration or OMB I don't think these issues have been really debated. This is a particular hit list of a very narrow group with a very particular set of tastes, which I think are not particularly well informed. I don't think it represents considered judgment, there hasn't been any intellectual discussion on it. We might have had a discussion. Maybe it doesn't matter, but I feel sort of dismissed: "Go away. We're not interested in you." That's the posture of these cuts.

It's not that whatever has—you know, somebody has set up—some commission has asked people, sort of had a reasonable consideration of it, or at least has laid it out on the table.

Mr. GREGG. Thank you.

Mr. WALGREN. Along the same line, the question I have is: We're now coming to the committee to in many ways perhaps not so much decide whether cuts should be made, but the allocation of the cuts, and that is setting the priorities within the National Science Foundation. The difficulty we have is that we as a body have our own limitations in our ability to do that, information not being the least of them, and background being even a greater limitation.

The problem is that apparently within the time constraints of the political process that Mrs. Heckler referred to, the National Science Foundation was not given an opportunity to allocate those cuts. My question is: Who would have the best judgment in allocating those cuts? Would you prefer the National Science Board to allocate cuts among the National Science Foundation programs? Would that be unwieldy?

Dr. KLEIN. Well, I would have great confidence in that Board. I mean, that's an administrative decision. I think one should say that the scientific professional community of people who participate in the activities, one way or another, of the National Science Foundation, that has participated as donors or recipients or researchers, should participate to the extent that time allows, but one would say we would have great confidence in the Board in making those choices.

Mr. WALGREN. Dr. Griliches?

Dr. GRILICHES. I basically said the same thing in my testimony. I would be willing to go in this direction because luckily, the overall NSF budget has been in good shape. With a $1 billion budget, I think almost any organization, given enough notice, given time to get its house in order, can absorb a 10-percent cut and figure out some reasonable way of where it will cause the least damage. But what has happened is that almost all of the cuts have been targeted in just a few areas, basically decimating them and leaving the rest untouched, and that seems kind of both strange, because the scientific rationale for that isn't apparent, and inefficient, because it's going to really cripple some of these operations.

While there are a lot of claims and there are a lot of things that one could do in all of these areas, it is also reasonable that we could survive a 10-percent-across-the-board cut, a variance of 15 percent, 20 percent somewhere, 5 percent somewhere else. I would be perfectly happy to let Dr. Slaughter, together with the program officers and with the advice of the National Science Board, figure out how to do it. That's why we get good people to run it.

Mr. **Walgren**. The most interesting thing about this whole process is that the real question is who sets the priority within the National Science Foundation? That's the real question. This process has resulted in outside forces setting the priorities within the National Science Foundation. There seems to me to be an uncoupling between the level of public understanding, that every area is being asked to take its cuts, and what is actually happening, where these cuts are being so focused as to zero out efforts, where they could be distributed much more evenly.

Well, we certainly appreciate your having come, particularly your underlining the real contribution and the potential of the economic sciences, as well as emphasizing the importance of considering the investment quality of expenditures in this area with respect to future economic strength.

Let me go off the record 1 minute.

[Discussion off the record.]

Mr. **Walgren**. On the record. Well, thank you very much. We appreciate your contribution.

The third panel, and last for this morning, is made up of Dr. Kenneth Prewitt, currently the president of the Social Science Research Council and chairman of the Political Science Department of the University of Chicago; Dr. Henry Riecken, who is a professor of behavioral science at the University of Pennsylvania and has worked with a number of national committees in national assessment efforts, including the General Accounting Office Advisory Committees and several related to the Academy of Sciences; and, Dr. David Glass, professor of psychology and the director of the Biobehavioral Laboratory at the City University of New York. Dr. Glass is the president of the Academy of Behavioral Medicine Research, and has written broadly in that field.

Thank you very much, gentlemen, for coming, and please let me ask you to proceed as you wish.

Dr. Prewitt?

[A biographical sketch of Dr. Prewitt follows:]

Social Science Research Council
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KENNETH PREWITT

Dr. Kenneth Prewitt is president of the Social Science Research Council, a national coordinating council established in 1923. During its 57-year history, the Council has seeked to advance research in the social sciences in a wide variety of ways: the appointment of committees of scholars to set priorities and make plans for critical areas of social science research; the improvement of research training through training institutes and fellowship programs; the support of individual research through postdoctoral grants; the sponsorship of research conferences, often interdisciplinary and international; and the sponsorship of books and other research publications that may result from these activities. The international activities of the Council include the joint sponsorship with the American Council of Learned Societies of 14 committees concerned with encouraging research on specific countries or regions of the world by means of dissertation research fellowships, postdoctoral grants, international research conferences, scholarly exchanges, library development, and publications.

Dr. Prewitt received his Ph.D. in political science at Stanford University, and has taught at Stanford, Washington University, and Columbia University as well as spending several years teaching and conducting research in East Africa. His major university home has been the University of Chicago, where he has served as chairman of the Political Science Department and, for three years, director of the National Opinion Research Center. He has authored or co-authored a dozen books and has frequently published in scholarly journals. He serves on the editorial board of a half-dozen social science journals, as well as having board membership on several national and international social science organizations.

STATEMENT OF DR. KENNETH PREWITT, PRESIDENT, SOCIAL SCIENCE RESEARCH COUNCIL, AND, PROFESSOR (ON LEAVE), POLITICAL SCIENCE DEPARTMENT, UNIVERSITY OF CHIGAGO

Dr. PREWITT. Well, Mr. Chairman, time is short, so I will speak rather quickly to the central issue, which is the proposed fiscal year 1982 budget for the support of the behavioral and social sciences in the National Science Foundation.

I appreciate the constraints under which Dr. Slaughter spoke. I also appreciate his rather firm endorsement of the social and behavioral sciences. I have to respectfully disagree with him.

To reduce sharply or to eliminate the National Science Foundation support for these sciences is to cut the science out of them. The National Science Foundation has a unique and indispensable role in maintaining the research infrastructure of these disciplines.

There are other and larger supporters of the social sciences in both the private and the public sector, but these other funders are largely users. They do not see their task as providing the foundation for the development of the science, building the institutional base and building the data resources.

The proposed reduction in the NSF budget, when coupled with the reductions at the National Institute of Mental Health and the National Endowment for the Humanities, is analogous to taking radio telescopes away from astronomers, animal laboratories away from biologists, linear accelerators away from physicists.

Critics of the social sciences, even when they are familiar with these consequences, may say, "So what?" I ask the critics to examine the record, Mr. Chairman—the actual record—not the record fabricated out of accusations that take particular study titles out of context for purposes of ridicule, not the record which, in confusion, fails to distinguish social science from social policy or social reform, and not the record based on the false assumption that what we now know about people and societies is knowledge we have always had. The actual record is rather more impressive than the caricatures disseminated by these critics.

The record of which I speak extends over a half-century, the period which marks the growth of the empirical social sciences in the United States. No 10-minute commentary can summarize this record, but even a summary reveals one unmistakable message: For 50 years the social sciences have concentrated a large share of their research resources and intellectual attention on the issues which have been of deepest concern to this society.

The story starts toward the end of the 1920's, when President Herbert Hoover organized large numbers of social scientists for the preparation of "Recent Social Trends," volumes reporting the many facets of society affected by World War I and the Depression.

Throughout the 1930's, social science investigations were concerned with those topics brought to attention by the efforts of society to deal with the Depression: social security, internal migration, unemployment relief, agricultural prices, and labor market behavior. Indeed, the national, State and local statistical systems, without which governing this society would be a good deal more complicated than it already is, are constructed with the methods and the concepts of the social sciences, many of them developed during what was the Nation's worst domestic crisis in the 20th century.

In the 1940's, not surprisingly, social scientists turned their concepts and methods to war-related questions: civilian morale; the analysis of enemy propaganda; studies relevant to the recruitment, training, management and eventual discharge of the Armed Forces; the effects of the strategic bombing of Germany and Japan. Much of this research was sponsored by the Research Branch of the Information and Education Division of the War Department. A very impressive result of this research appears in the volumes of "The American Soldier."

The point system which was used to discharge the American soldier and to lead toward setting up the GI bill of rights was a result of this research. Indeed, the demobilization of the Armed Forces at the end of the war minimized both dislocation and feelings of resentment. The success at reintegrating World War II veterans into the society is an impressive accomplishment, based in part on social science research.

The response of the social sciences to the events of the 1950's is no less impressive than the Depression-related and war-related efforts of the two preceding decades. In the 1950's, attention turned outside the United States. As the prewar colonial empires disintegrated and our Nation became strategically and economically involved with new nations around the world, hundreds of scholars went abroad to study the cultures and languages of the newly independent nations.

The 1950's gave birth to university programs in which scholars from various social science and humanistic disciplines conducted research which helped the United States find its way in what had been a very foreign world. The establishment of international studies is one of the great achievements of American higher education, and is to this day the envy of governments and academic communities around the world, many of whom are presently copying our programs.

The domestic ferment of the 1960's was mirrored in a growth of interest among social scientists in race relations, urban problems, schooling, internal migration, as well as immigration. It was, of course, also a decade in which something loosely called the policy sciences gained prominence.

Several misunderstandings about the social sciences, I am convinced, emerged from this period. I do not have time to lay out all of these misunderstandings, but I do want to put one into the record. Persons who opposed the policies, especially the Great Society programs of President Johnson, have sometimes opposed not just the policies but also the social science methods and concepts applied in the policy process. This confuses the science with the social program and grants to social science much more influence than it had or will ever have.

Social science research does not determine policy. Policy, as Members of the Congress well know, is a matter of political deliberation, accommodation of diverse interests, and the creature of social values. It is an exercise in moral choice and political judgment.

To what extent social science research is relevant to the policy process is, as we all know, a matter of some dispute. Clearly, if the information provided the policymaker is faulty, or if the concepts are misleading, or if the evaluation is misspecified, or the predictive model is in error, then the science which supplied the information, concepts, evaluation or prediction should indeed be criticized. And there is a virtual industry within the social sciences which advances and encourages such criticism.

Often, however, in public discourse one hears a different criticism. Not liking the policy, the critic also dismisses or ridicules the tools and aids used by those who make the policy.

Unfortunately, this guilt by association is not matched with a credit by association. When social science methods or concepts contribute to effective social programs or, as has often been the case, prevent a mistaken program from being enacted, the credit is claimed by the political process and is not shared with the social science responsible for the demographic projection, the economic indicator, the sociological concept or the organizational analyses found useful. Though this is an understandable assignment of credit, I believe it does lead to a systematic under-appreciation of social science research.

The 1970's were a continuation of previously exhibited patterns. Among other things, the 1970's witnessed a concern about the unintended consequences of Government efforts to regulate economic and social activities. This concern was systematically voiced by economists, sociologists and political scientists, whose research efforts became the empirical foundation for a public discussion of deregulation.

In the 1970's, as we will hear from Dr. Glass, the research field of behavioral medicine made enormous advances, partially in response to a growing concern about health and health costs.

The 1970's were a decade of sharply increased global interdependence, and social scientists increased their research efforts on international labor migration, capital and commodity flows, and strategic issues.

More pointedly, the decade just passed was a time of doubt about how well certain social policies from the 1960's were working. Social scientists responded by establishing specialized methods for evaluating the consequences of particular programs.

The record, I assert, is clear. It is not a record to be revealed by confusing social science with social reform, by ridiculing carefully selected project titles, or by the superficial claim that we knew it all along. It is a record which demonstrates that for five decades social science, as a major part of its research activities, has contributed to this society's capacity to understand and cope with its most pressing concerns. The historical record, if extrapolated, offers hints about the future.

Mr. Chairman, I now skip over to the following page.

What can we expect of the 1980's? If economic productivity, industrial revitalization, social innovation and decentralization are issues on the agenda, I contend there will be serious and sustained attention to these matters by some of the best social scientists in the country, the contemporary equivalents of those earlier scholars who conducted the Depression-related research in the 1930's, the war-related research in the 1940's, the foreign area studies of the 1950's, and so forth.

Indeed, the work is already underway. In the current issue of Scientific American, the lead article presents, in human capital terms, an innovative way to look at the place of the service sector in the economic productivity of the United States. In a very recent issue of the magazine Science, the lead article reports research on the conditions which transform a scientific innovation into practical advances in weaponry or biomedical therapies. This research, as reported in Science, on the payoff of different forms of research and development, goes straight to the issue of innovation and productivity.

Conceptualization and empirical research are two of the ways in which social science will address issues of innovation and productivity. In so doing, social science can, for example, help to establish the boundaries within which innovations might reasonably be attempted.

A reindustrialization program that fails to take account of both the informal labor market and the hidden economy—discoveries of the social sciences in the last decade or so—is no more likely to work than a psychiatric therapy program that ignores unconscious motivation.

Moreover, social science can evaluate whether an innovation has, in fact, worked. For example, research on the success of recent social and medical innovations concludes that, when put to trial, only about 50 percent of the innovations were successful.

Social science can also conceptualize and develop measures of social inventions. Our contribution to the conceptual armament of this society is impressive: externalities, relative deprivation, identity crisis, GNP, assimilation, the hidden economy, political party identification, unanticipated consequences—these are all concepts which emerged from the work of social scientists and their research activities.

Our contribution to measurement and methods is equally impressive: standardized aptitude testing, attitude surveys, demographic rates, participant observation, cartographic analysis, industrial productivity indicators, ethnographic description. These conceptual and measurement skills will now be turned to questions of innovation and productivity; thus, the search for new economic and institutional forms, risk analysis under conditions of uncertainty, the study of decision process, means of reaching consensus, investigation of human creativity, and competence.

Social science, already international in scope, will help import and transform for local consumption ideas and organizational arrangements which elsewhere have proved their value to economic productivity.

Finally, social science itself will be the source of social innovations. Previous examples include: econometric forecasting, about which we heard from Professor Klein, demographic projections, input-output matrices, standardized testing, man-machine system design, operant conditioning.

Presently, scholars are working on management strategies for complex organizations, risk analysis, optimal sampling design, all areas in which innovations will be forthcoming.

Mr. Chairman, the argument I advance is very straightforward and simple. If I may be theatrical, here in my left hand is a copy of Recent Social Trends—social science research commissioned by President Hoover in order to help the Nation cope with an earlier economic crisis. Here in my right hand are recent issues of Scientific American and the magazine Science, which report social science research specifically relevant to contemporary economic difficulties. In between is a half century of scientific work on problems facing this society.

I believe that the scientific and the social record will show that the behavioral and the social sciences have earned a rightful place in the program of the National Science Foundation. I believe that the proposed cuts, if allowed to stand, will effectively dismantle the infrastructure, the data and the institutional arrangements, the training programs, which have sustained our sort of scientific development.

I am going to, if I may, take a moment to answer directly the question that you put to Professors Klein and Griliches.

I would urge this committee—living within the budget cuts that have now been proposed to the National Science Foundation—to not only recommend that the National Science Foundation and National Science Board administer the new allocations, but also I would recommend to this committee that you do so within certain guidelines. I think we've heard testimony already today suggesting that the National Science Foundation is under some pressure from the administration. It itself is an Executive agency, and I urge this other branch of Government, the legislative branch, to exercise some leadership to make its independent decision and come to its own judgment about the value of the behavioral and social sciences, and certainly to allow the National Science Board and the staff of the Foundation to administer some cuts, but I would suggest to you that you might provide some guidelines and suggest it's very difficult to run the kind of program that I think we need to run in these sciences with anything like a 75-percent or 60-percent cut.

We know what we're looking at. We're really looking at the dismantling of the support for the kind of social and behavioral sciences that I think have been around in an important, useful way to this society for more than a half century.

Thank you.

[The prepared statement of Dr. Prewitt follows:]

TESTIMONY

of

Kenneth Prewitt
President
Social Science Research Council

Members of Congress. My name is Kenneth Prewitt. I am presently the President of the Social Science Research Council, an organization whose Board of Directors includes representatives from the American Anthropological Association, the American Economic Association, the American Historical Association, the American Political Science Association, the American Psychological Association, the American Sociological Association, and the American Statistical Association, as well as other distinguished behavioral and social scientists from research universities and institutions.

Time is short. I will quickly speak to the central issue -- the proposed FY '82 budget for support of the behavioral and social sciences in the National Science Foundation. In shifting the judgment about the allocation of scientific resources from a deliberative process knowledgeable about the scientific merit and public benefit of specific science programs to a political/budgetary process, the proposed budget has important consequences that are probably unintended.

To reduce sharply or to eliminate NSF support for the behavioral and social sciences is to cut the "science" out of the practice of these disciplines. NSF has a unique and indispensable role in maintaining the research infrastructure of the behavioral and social sciences. There are other and even larger supporters of social science research, in both the private and the public sectors. These other funders are primarily users of social science and they thus provide important although somewhat indirect support for the scientific side of the behavioral and social sciences. Only rarely do these user-oriented funders view their responsibility as building the institutional base and the data resources which allow a science to progress. The proposed reduction in the NSF budget for behavioral and social sciences -- when coupled with the reductions at both National Institute of Mental Health and the National Endowment for the Humanities -- is analogous to taking radio telescopes away from astronomers, animal laboratories away from biologists, linear accelerators away from physicists.

Critics of the social sciences, even when they are familiar with these consequences, may say, "So what?". I ask the critics to examine the record. The actual record, not the record fabricated out of accusations that take particular study titles out of context for purposes of ridicule; not the record which, in confusion, fails to distinguish social science from social policy or social reform; not the record based on the false assumption that what we know now about people and societies is knowledge we have always had. The actual record is rather more impressive than the caricatures disseminated by these critics.

The record of which I speak extends over a half century -- the period which marks the growth of the empirical social sciences in the United States. No ten-minute commentary can summarize this record, but even a summary reveals one unmistakable message. For fifty years the social sciences have concentrated a large share of their research resources and intellectual attention on the issues which have been of deepest concern to the society.

The story starts toward the end of the 1920s, when President Herbert Hoover organized large numbers of social scientists for the preparation of Recent Social Trends, two volumes reporting on the many facets of society affected by World War I and the Depression. Throughout the 1930s, social science investigations were concerned with those topics brought to attention by the efforts of society to deal with the Depression: social security, internal migration, unemployment relief, agricultural prices, and labor market behavior. A Committee on Government Statistics and Information Services was organized by the Social Science Research Council in 1933. It led to the Central Statistical Board and subsequently to a central body responsible for the standardization of statistics and statistical quality. During the 1930s, Simon Kuznets did the work on the measurement of consumption, savings, and investment components of national income which subsequently became the basis for national income and GNP estimates. The national, state, and local statistical systems, without which governing this society would be a great deal more complicated than it already is, are constructed with the methods and concepts of the social sciences, many of them developed during what was the nation's worst domestic crisis in the 20th century.

In the 1940s, not surprisingly, social scientists turned their concepts and methods to war-related questions: civilian morale; the analysis of enemy propaganda; studies relevant to the recruitment, training, management, and eventual discharge of the armed forces; the effects of the strategic bombing of Germany and Japan. Much of this research was sponsored by the Research Branch of the Information and Education Division of the War Department. An impressive result of the research effort appears in the volumes of The American Soldier. The project enlisted the efforts of dozens of social scientists. Of all the research results reported through these studies, the one that has had the most impact is that of relative deprivation. Faced with data reporting that soldiers in the Air Force, a rapid promotion branch, were more dissatisfied with promotion opportunities than soldiers in the Military Police, a slow promotion branch, social scientists offered the explanation that deprivation is relative to expectations, including the expectations of others. This now-obvious explanation -- like so many other now-obvious social science concepts and findings -- has had impact on the development of our science and many specific policies. For example, the research in The American Soldier led to the "point system," a procedure for demobilizing the armed forces at the end of the war that minimized both dislocation and feelings of resentment. The success at re-integrating World War II veterans into the society is an impressive accomplishment, based in part on social science research.

The response of social science to the events of the 1950s is no less impressive than the Depression-related and war-related efforts of the two preceding decades. In the 1950s, attention turned outside the United States. As the prewar colonial empires disintegrated and our nation became strategically and economically involved with new nations around the world, hundreds of scholars went abroad to study the cultures and languages of the newly-independent nations. World War II had demonstrated how ignorant Americans were of non-Western places and peoples. Indeed, in announcing the Point Four program in 1949, President Truman noted the scarcity of experts who knew anything about countries to which development funds were to be sent. The 1950s gave birth to university programs in which scholars from various social science and humanistic disciplines conducted research which helped the U.S. find its way in what had been a very foreign world. The establishment of international studies is one of the great achievements of American higher education, and is to this day the envy of governments and academic communities around the world -- many of whom are presently copying our programs.

The domestic ferment of the 1960s was mirrored in a growth of interest among social scientists in race relations, urban problems, schooling, internal migration, as well as immigration. It was, of course, also a decade in which something loosely called "the policy sciences" gained prominence. Several misunderstandings about the social sciences, I am convinced, emerged from this period. Persons who opposed the policies, especially the Great Society programs of President Johnson, have sometimes opposed not just the policies but also the social science methods and concepts applied in the policy process. This confuses the science with the social program, and grants to social science much more influence than it had or will ever have. Social science research does not determine policy. Policy, as members of the Congress well know, is a matter of political deliberation; it is an accomodation of diverse interests and the creature of social values; it is an exercise in moral choice and political judgment. To what extent social science research is relevant to the policy process is, as we all know, a matter of some dispute. Clearly if the information provided the policy maker is faulty or if the concepts are misleading or if the evaluation is misspecified or if the predictive model is in error, then the science which supplied the information, concepts, evaluation, or prediction should indeed be criticized. And there is a virtual industry within the social sciences which advances and encourages such criticism. Often, however, in public discourse one hears a different criticism. Not liking the policy, the critic also dismisses or ridicules the tools and aids used by those who make the policy.

Unfortunately, this guilt by association is not matched with a credit by association. When social science methods or concepts contribute to effective social programs -- or, as has often been the case, prevent a mistaken program from being enacted, the credit is claimed by the political process and is not shared with the social science responsible for the demographic projection or the economic indicator or the sociological concept or the organizational analysis found useful. Though this is an understandable assignment of credit, it does lead to a systematic underappreciation of social science research.

The 1960s stand as further confirmation of a more general point. The social sciences do not create a nation's agenda. Far more powerful currents than research determine the issues that perplex and preoccupy a society. These currents affect business decisions, election returns, media attention, policy reforms, and citizen attitudes. They also affect what social science studies; not entirely, of course, but to an extent which easily confirms the argument I seek to make.

The 1970s were a continuation of previously exhibited patterns. Among other things, the 1970s witnessed a concern about the unintended consequences of government efforts to regulate economic and social activities. This concern was systematically voiced by economists, sociologists, and political scientists whose research efforts became the empirical foundation for a public discussion of deregulation. In the 1970s, the research field of behavioral medicine made enormous advances, partially in response to a growing concern about health and health costs. The 1970s were a decade of sharply increased global interdependence, and social scientists increased their research efforts on international labor migration, capital and commodity flows, and strategic issues. More pointedly, the decade just passed was a time of doubt about how well certain social policies from the 1960s were working. Social scientists responded by establishing specialized methods for evaluating the consequences of particular programs.

The record, I assert, is clear. It is not a record to be revealed by confusing social science with social reform, by ridiculing carefully selected project titles, or by the superficial claim that "we knew it all along." It is a record which demonstrates that for five decades social science, as a major part of its research activities, has contributed to this society's capacity to understand and cope with its most pressing concerns. The historical record, if extrapolated, offers hints about the future. But before turning to the 1980s, important qualifications should be recorded.

First, the sketch just presented does not pretend to be a history of the social sciences in the United States. Much that was important is not captured in the few themes stressed. Second, in emphasizing that a large share of social scientific resources has been devoted to issues of deepest concern to the society, I do not imply that research reports only good news. Very often the research results do not accord with the way those in responsible positions believe the world to be, or wish it to be. Demographers show that education or housing or the health plans of local governments are thwarted by unanticipated decreases, or incresaes, in crucial age groups; the economic concept of externalities obliges us to take account of the environmental costs of an imperfectly regulated market system; sociologists and economists are mapping a large "hidden economy and informal labor sector," the presence of which argues against any simple solutions to declining industrial productivity; political scientists anticipate the deliterious effect on political parties of various reforms in party rules; evaluation research has shown the faulty assumptions of programs as diverse as housing subsidies, bonus systems, health-cost containment schemes, and curriculum reform. Very often social science research challenges received wisdom. This, of course, is not a reason for reducing a nation's research effort anymore than we should call off elections because voter sentiment may be bad news for the political party in power. Early warning systems are often what a society needs -- such as warnings about the perverse incentives in certain taxation policies, the growth of the hidden economy,the changing dependency ratio as fertility declines and the population ages. It is not accidental that the phrase "unanticipated consequences," now a term in everyday vocabulary, was introduced by a social scientist. Social science looks for second and third order consequences of actions planned with other ends in view. The unintended consequences of an intervention in a complex system may be at odds with and even detrimental to the intended effect.

A third important qualification is that social science, especially where it speaks to complex social questions, is far from a perfect voice. Social science can provide necessary information; it can reveal unexpected associations; it can provide concepts and new ways of thinking about matters. It does not, thereby, solve social problems.

The next chapter of the story anticipates rather than records. What can we expect of the 1980s? If economic productivity, industrial revitalization, social innovation, and decentralization are issues on the agenda, there will be serious and sustained attention to these matters by some of the best social scientists in the country, the contemporary equivalents of those earlier scholars who conducted the Depression-related research in the 1930s or the war-related research in the 1940s or the foreign area studies of the 1950s. Indeed, the work is already under way. In the current issue of Scientific American the lead article presents, in human capital terms, an innovative way to look at the place of the service sector in the economic productivity of the United States. In a recent issue of Science the lead article reports research on the conditions which transform a scientific innovation into practical advances in weaponry or biomedical therapies. This research, on the pay-off of different forms of research and development, goes straight to the issue of innovation and productivity.

Conceptualization and empirical research are two of the ways in which social science will address issues of innovation and productivity. In so doing, social science can, for example, help to establish the boundaries within which innovations might reasonably be attempted. A reindustrialization program that fails to take account of both the informal labor market and the hidden economy is no more likely to work than a psychiatric therapy program that ignores unconscious motivation. Moreover, social science can evaluate whether an innovation has, in fact, worked. For example, research on the success of recent social and medical innovations concludes that, when put to trial, only about 50 per cent of these innovations were successful. Social science can also conceptualize and develop measures of social inventions. Our contribution to the conceptual armament of this society is impressive: externalities, relative deprivation, identity crisis, GNP, assimilation, the hidden economy, political party identification, unanticipated consequences; all concepts from social science research. Our contribution to measurement and methods is equally impressive: standardized aptitude testing, attitude surveys, demographic rates, participant observation, cartographic analysis, industrial productivity indicators, ethnographic description. These conceptual and measurement skills will now be turned to questions of innovation and productivity; thus,the search for new economic and institutional forms, risk analysis under conditions of uncertainty, the study of decision processes and means of reaching consensus, the investigation of human creativity and competence. Social science, already international in scope, will help import and transform for local consumption those ideas and organizational arrangements which elsewhere have proven their value to economic productivity.

Finally, social science itself will be the source of social innovations. Previous examples include econometric forecasting, demographic projections, input-output matrices, standardized testing, man-machine system design, operant conditioning. Presently scholars are working on management strategies for complex organizations, on rish analysis, and on optimal sampling design -- all areas in which innovations will be forthcoming.

The argument I advance is simple enough. Here in my left hand is a copy of Recent Social Trends -- social science research commissioned by President Hoover in order to help the nation cope with an economic crisis. Here in my right hand are recent issues of Scientific American and Science, which report social science research specifically relevant to contemporary economic difficulties. In between is a half centery of scientific work on problems facing this society. I believe that the scientific and social record will show that the behavioral and social sciences have earned a rightful place in the program of the National Science Foundation.

Mr. WALGREN. Thank you very much, Dr. Prewitt.

Dr. Riecken?

[A biographical sketch of Dr. Riecken follows:]

Henry W. Riecken
Professor of Behavioral Science
School of Medicine, University of Pennsylvania (Philadelphia)

(on leave 1980-81 at the National Library of Medicine)

Formerly:

President, Social Science Research Council (New York)
Fellow, Center for Advanced Study in the Behavioral Sciences (Palo Alto)
Assistant Director (Social Sciences), National Science Foundation (Washington)
Professor, University of Minnesota
Lecturer, Harvard University

Concurrently:

Board of Directors, Foundation for Child Development (New York)
Board of Governors, Center for Creative Leadership (Greensboro)
Chairman Board of Trustees, Bureau of Social Science Research (Washington)
Educator Advisory Committee, U.S. General Accounting Office (Washington)
Visiting Committee, Institute for Program Evaluation, U.S. General Accounting Office (Washington)
Charter Member Institute of Medicine, National Academy of Sciences (Washington)
Commission on Human Resources, National Academy of Sciences (Washington)

Publications

Books:
The Volunteer Work Camp; A Psychological Evaluation
When Prophecy Fails
Social Experimentation
Experimenting for Public Policy Development
Evaluating the Impact of Nutrition and Health Programs

Articles in Professional Journals

STATEMENT OF DR. HENRY W. RIECKEN, PROFESSOR OF BEHAVIORAL SCIENCE, SCHOOL OF MEDICINE, UNIVERSITY OF PENNSYLVANIA

Dr. RIECKEN. Thank you, sir.

As you pointed out, Mr. Chairman, I'm professor of behavioral science at the medical school of the University of Pennsylvania and it's in that capacity that I speak to you today, although I'm currently on leave from my university at the National Library of Medicine.

My statement and my views on the importance of the behavioral and social sciences come from about 40 years of experience in behavioral research, in teaching the sciences of behavior and in managing research organizations. I want to emphasize that I'm speaking for myself, as a professional, not as a representative of any organization or institution. I think it will become clear as I go along that I am not representing the position of this administration.

I strongly support the basic research programs in social and behavioral sciences at the National Science Foundation. I consider them to be of long-range value to this country, and fully worthy of public support. I also believe that these sciences have repeatedly demonstrated their value, their worth and their usefulness.

And in the course of my experience, I've come to conclusions about these sciences that are remarkably similar to those of my colleague, Dr. Prewitt; namely, that they are the most misunderstood of any sciences we have. Many people seem to find it difficult to believe that there is a science of behavior, and I think that's probably because the behavioral sciences deal with phenomena that, unlike astronomy or microbiology, are well within everyday experience, so everybody can, in some sense, consider himself to be an expert, an experienced observer of human behavior. And there are other people who think, as Dr. Prewitt said, that behavioral sciences are equivalent to social reform and that social sciences are nothing but social commentary.

Now, I think these views are wrong. In fact, most behavioral and social scientists spend most of their time doing exactly what other kinds of scientists do—namely, making observations and measurements—and a lot of effort has gone into improving the measurement of behavioral and social phenomena. A lot more is still needed, since the phenomena are complicated and complexly determined.

I'd like to give some brief examples of why it's important to have systematic observation and careful measurement. I'm going to extract these from the testimony and not read it word for word, with your permission.

Let me start with an example that came to my attention a few days ago when the Board of Directors of the Foundation for Child Development met to review some project grants. One of the projects we approved bears on the apparent increase in the incidence of child abuse. Now, in the city of New York, reported child abuse and neglect cases have increased over the last 3 years, whereas the number of caseworkers available to investigate these incidents hasn't. And one way of adapting to that was to try to divide the reported incidents, as they came in, into two groups, high risk and low risk, trying to make an assessment of how significant the reported incident was.

You see, not all incidents of reported child abuse can be taken equally seriously. Sometimes a neighbor or a relative has simply misunderstood and misinterpreted an insignificant incident. Other times, the report is made with great reluctance, usually by a close relative, and only when the child's life is in danger. So it's terribly important to make an early judgment so you can do triage on these cases.

What's the best way to do that? Well, the obvious suggestion is to rely on the experienced judgment of case workers. But 2 years of experience showed that in a substantial number of incidents, the cases were misclassified on intake; that is, the worker was not able to make a correct judgment as to the seriousness of the case. Mistaken assignment left some children at high risk, whereas other children, who were at low risk, took up an undue share of the agency's attention and resources.

The agency called in some behavioral scientists, who developed a screening technique, a risk assessment scale that could be used by case workers to judge the probable severity or the seriousness of the reported incident. They used well-established psychometric methods, methods that had been worked out many years ago. They analyzed the information available in agency records to establish the relationship between the intake characteristics and the eventual outcome, and from that derived a scale that can be easily used and applied quickly, which greatly increased the efficiency of the agency and probably saved the lives of some children.

That's just 1 example of 100 I could mention of a behavioral technology that dates back anywhere from 20 to 40 years, based on basic laboratory work which was undertaken for entirely different purposes.

I could have cited other examples. For example, a dramatic one is the behavioral profile that was constructed by psychologists at the Federal Aviation Agency back in 1968 and 1969, long before there were metal detectors and cabin baggage X-ray at the boarding gate. This profile enabled airline personnel to make a quick judgment as to whether somebody was a probable hijacker or not, and after that was put into effect the number of hijackings dropped spectacularly.

I can take a second example from the world of sports which is lighter and perhaps not quite so important to the Nation, but it's important in the national attention, sir. Even if you don't follow the ACC tournament, or if you're not a World Series watcher, you probably have heard of the notion of the home court advantage, the home field edge, the thing that the home team has over the visitors. There are lots of speculations as to whether there is such a thing or not and, if so, how could it come about?

Well, careful study of this by some sociologists has shown that there is a real home field advantage. That's a tricky thing to do, because you have to compare results from unevenly matched teams, as well as the simply home/away comparison. The home court advantage is real.

Second, the advantage is greater in some sports than others. It's greater, for example, in basketball and hockey than it is in football and baseball.

Third, it's greater when the crowd is larger, and apparently there are real crowd effects.

But, fourth, the home advantage is the result of some quite specific kinds of behavior on the part of the players. By systematic observation and counting of various kinds of actions on the part of home and visiting teams, social scientists found substantial differences. In basketball, for instance, the study showed that home teams were more successful than visitors in certain kinds of risky, aggressive behavior, specifically rebounds, steals, blocked shots. And they've gotten parallel results in baseball, where you get more bases per hit, so to speak, from the home team than from the visitors, probably because of more aggressive base running, taking more chances.

But when it comes to other kinds of aggressive behavior, like committing fouls, then the visitors are more aggressive. That's true for basketball and for soccer, for example.

Now, is there a contradiction here? No, because two different types of aggression are involved. One is what behavioral scientists call "instrumental aggression"—that is, forceful behavior in the interest of achieving some goal—and this is the kind of aggression that manifests itself as daring or risk-taking, seizing the initiative. And the other kind is "expressive" or "reactive" and is the result of frustration. It's the kind of aggression that leads to making fouls and to losing ball games.

Now, this distinction between instrumental aggression and expressive aggression is the outcome of some much, much earlier work, many years ago, looking at the consequences of frustrating human subjects in various kinds of conditions. But its application here is a good example of how a fundamental conceptual distinction later, much later, 20 years later, comes to help in the observation and the explanation of a situation that is somewhat confused and opaque.

My third example takes us into the question of how mind and body interact in disease. There's not time enough to go into the details, but in brief, this is the story of how a psychological test could distinguish between sick people and people who were not sick, when all were equally infected with an influenza virus. The study was carried out during an influenza epidemic at a military base, and the investigators isolated for special study two groups of workers at the base, all of whom showed the conventional organic sign of influenza, of infection; that is, a fourfold rise in antibody titer. But one group were the people who felt ill, who stayed in bed, who didn't work. The other group reported for work, didn't complain and carried on business as usual.

Now, what characteristics distinguished these two groups? Not physiological measures, not hematological findings, not medical history items. The thing that distinguished the individuals were their performance on a psychological test called the Minnesota Multiphasic Personality Inventory. In other words, from a sample of equally infected people, the ones who felt ill were only psychologically different from those who didn't feel ill. Which leads to the question of what is influenza, anyway, and who has it? And these are basic questions that go to the very heart of human experience, as well as to the very basis of medical diagnosis and treatment.

Once again, it's possible to ask the question because of the prior existence of a validated, systemically developed behavioral measure, one that came into being more than two decades ago for quite different scientific purposes.

Now, Mr. Chairman, in my written testimony I discuss some other things, some of which may be touched upon by Professor Glass: the role of behavioral science, for example, in the study of pain and pain control; the role of behavioral science in basic research on language learning, with the implications that that has for mental retardation. I also discuss a number of social science areas where the support of data archives for research is important, archives whose data may bear on public policy.

I also point out in my written testimony, beginning on page 11, that this very body, the legislative branch of the Federal Government, itself makes extensive use of social science. The General Accounting Office, for example, under the stimulus of the Congressional Budgeting Act of 1974, created its own Institute for Program Evaluation, on whose advisory committee I serve. This Institute has the responsibility for improving the technical quality of GAO assessments of Government programs and for improving the congressional use of evaluative information in its decisionmaking.

And I might just depart from my written testimony for a moment, Mr. Chairman, to point out that in my recent discussions with the staff of this Institute, they have said that they are impressed by the quality of inquiries they now get from congressional committee staffs, and they think they're going to have to shape up and improve the GAO act so they can be appropriately prepared to deal with these congressional questions.

Well, the techniques of program evaluation were developed by sociologists, by psychologists and economists, largely, and the Institute at GAO is staffed by professional social scientists.

And I'd like to point out again what a leadtime is involved here. I myself did some work that was almost pioneering in program evaluation around 1950, but it was not until the late 1960's or the 1970's that evaluation studies became widespread, and not until 1974 that the Congress mandated GAO to conduct evaluations of Government programs.

And that figure, 20 years more or less, is probably not a bad estimate of the length of time that's needed to bring a new idea or a new technique from basic investigation to general use. Now, that means that today the NSF is supporting some research whose real usefulness cannot be known for two decades.

Who can make the judgment now with confidence that such basic research is not really worth supporting? Who can say that behavioral science is not worthy of public support? Surely the best placed people to make that judgment are the scientists themselves. The peer review system is the best means we have of judging how to choose the most promising research.

And that's not just my own opinion. I recently had the pleasure of meeting Dr. Bengt Gustafson, the former secretary—recently retired secretary—of the Nobel Prize Committee. He's given a great deal of attention to the question of why some nations get more than their share of Nobel Prizes, especially the United States. He's come to the conclusion that nations which depend upon the peer review system for evaluating scientific work do in fact produce the best and, hence, they get the greatest number of prizes. That's the only distinguishing feature of the various nations' systems of science support that Gustafson can find to explain the difference.

And the lesson should not be lost on us, sir, that the best judges of what to encourage and what to eliminate in science are scientists themselves.

Finally, let me close by calling your attention to a statement that's of great importance to those of us who call Pennsylvania our home, a statement from John Kemeny, president of Dartmouth and a distinguished mathematician, who was the chairman of the Presidential Commission To Investigate the Nuclear Powerplant Accident at Three Mile Island. In an article in the Technology Review, Dr. Kemeny writes about the lessons of Three Mile Island. He says:

> We started our work with the prior conviction that the big problem was equipment. But our overwhelming conclusion was that the basic equipment was amazingly good; it was the control room that was terribly designed from the point of view of the people who had to use it. The Commission's attention slowly but steadily shifted, almost completely, from equipment to people. We found that this was one of the most horrendous people problems we had ever encountered.

It's hard for me to imagine a better statement or a more eloquent argument for the support of behavioral science.

Thank you, sir.

[The prepared statement of Dr. Riechen follows:]

Statement of
Dr. Henry W. Riecken

My name is Henry Riecken and I am Professor of Behavioral Science at the Medical School of the University of Pennsylvania. It is in that capacity that I appear before you today, although I am currently on leave from my University and spending the year at the National Library of Medicine. My statement and my views on the importance of the behavioral and social sciences come from about forty years of experience--virtually all of my professional life--in behavioral research, in teaching the sciences of behavior and in managing social research organizations. I want to emphasize that I am speaking for myself, as a professional, not as a representative of any organization or institution.

I strongly support the basic research programs in social and behavioral sciences at the National Science Foundation. I consider them to be of long-range value to this country and fully worthy of public support. I also believe that the behavioral and social sciences have repeatedly demonstrated their value, worth and usefulness.

In the course of my experience in these fields, I have come to believe that these sciences are the most misunderstood of any we have. Many people seem to find it difficult to believe that there is a science of behavior; and I think that's because behavioral sciences deal with phenomena that, unlike astronomy or microbiology, are well within everyday experience. So everyone can, in some sense, consider himself an expert, an experienced observer of human behavior. Some people do not make any distinction between social science and social reform. And others think that social scientists only write social commentary--just another expression of opinion about social problems, perhaps couched in unusually dense jargon.

I think these views are wrong. In fact, most behavioral and social scientists spend most of their time doing exactly what other kinds of scientists do: making observations and measurements. A lot of effort has gone into improving the measurement of behavioral and social phenomena and a lot more effort is still needed, since the phenomena are complicated and complexly determined.

Measurement of behavior is important for scientific behavioral research and I want today to illustrate how and why it's important. I thought that, instead of trying to impress you with statistics and intricate arguments, I would just tell a few stories about how social and behavioral measurements are used in various parts of our national life. I want to show how useful systematic observations and valid measurements of human behavior are. Let me give some examples.

Let me start with an example that came to my attention a few days ago when the Board of Directors of the Foundation for Child Development (formerly The Association for the Aid of Crippled Children) met to review and approve some project grants. One of the projects we reviewed bears on the apparent increase in the incidence of child abuse. In New York City the number of cases of child abuse and neglect reported to the Office of Special Services for Children (Human Resources Administration of New York City) increased from 17,000 in 1978, to 20,000 in 1979 and to 30,000 in 1980. The number of case workers to investigate these reported incidents has been constant for a number of years, for the City budget has been under severe pressure. In order to handle the increased load, the Office devised the idea of dividing the reported incidents into two groups--those which seemed to warrant full and detailed investigation in one group, and in another, the incidents that appeared to be less serious and might be looked into quickly and closed out. Not all reported incidents of child abuse turn out to be valid. Sometimes the neighbor or relative who makes the report has misunderstood or misperceived an insignificant incident. In other cases the report may be made with great reluctance and only where the child's life is in danger. So it is important to be able to judge early and accurately whether a reported incident is high risk or low risk.

What is the best way to make such a judgement?--Rely on the perceptive judgment of experienced case workers. Right?

Wrong. Two years of experience showed that a substantial number of high-risk cases (as shown by subsequent outcome) had been mistakenly assigned to the procedure for early closing while a number of low-risk cases were being investigated by more intensive methods, which also took longer and cost more. In other words, mistaken assignment left some children at high risk while others, who were at low risk, took up an undue share of the agency's attention and resources.

Fortunately, the agency called in some behavioral scientists to help with the problem. They developed a screening technique, a risk assessment scale that could be used by case workers to judge the probable severity or seriousness of the reported incident The behavioral scientists devised this scale by using well-established psychometric principles and techniques. They analyzed information available in agency records to establish the relationship between characteristics of the case on intake and the pattern of outcomes three years later. The scale was validated by trying it out on a sample of newly reported cases which were also followed up. The scale is easy to use,and it can be applied quickly. It greatly increased the efficiency of the agency and probably saved the lives of some children.

This scale is just one example of a behavioral technology that is grounded in basic research on behavioral measurement that is anywhere from 20 to 40 years old. It is only one example among many. I could just as easily have cited the example of the "behavioral profile" developed in 1968 or 1969 to detect potential airplane hijackers. Before there were metal detectors and cabin baggage x-ray machines in airports, psychologists at the Federal Aviation Administration developed a simple, easily applied observational scale that could be used by airline personnel to identify high probability hijackers. After this "boarding gate defense" was put into practice (and before the screening-by-hardware was in place) the

the number of successful skyjackings declined abruptly. This development of the hijacker screening profile was based on the same basic principles and techniques of psychometrics that were developed in the laboratory, out of a basic scientific curiosity several decades ago.

A second example. Sociologists are not just interested in Doing Good. Sometimes, they're interested in Who is Doing Better?... or What Makes a Team Win? There is a social science of sports and I want to give one example that shows how applied science rests on earlier basic research.

There is a widely held belief in something called the "home court advantage"--the "home field edge." There are lots of speculations about why the home team has an advantage, such as: the home team knows the grounds and the playing area better--they know how the ball bounces on the infield turf or how much rebound from a puck slammed against the dasher. Or maybe the visitors are fatigued by their travel and not as sharp. And possibly other explanations. What is know about the "home court advantage"?

First of all, it's real. That has been demonstrated by repeated statistical analyses in various sports--itself a tricky matter because you need to correct for difference in team quality because some contests are between unevenly matched teams. But the home advantage is real.

Second, the advantage seems to be greater in some sports than others--it's greater in basketball and hockey, for instance, than it is in baseball or football.

Thirdly, the home advantage is greater when the crowd is larger. These are real audience affects and they are magnified in the indoor games, where the crowd and the noise are closer to the players and more contained by the playing arena.

But, fourthly, the home advantage is the result of some quite specific kinds of behavior on the part of the players. Social scientists systematically observed and counted various actions on the part of home and visiting players and found substantial differences. In basketball, for example, the study showed that home teams were more successful than visitors in certain kinds of risky, aggressive behavior, specifically; rebounds, steals, and blocking shots. (Parallel results have been obtained in baseball: for instance, home teams score more runs in proportion to hits than visitors do, probably because of more daring and aggressive base running.)

But when it comes to other kinds of aggressive behavior, like committing fouls, the results show it's the visitors who are more "aggressive". Both in basketball and in soccer, visitors commit more fouls than home teams. Is there a contradiction here?

No, because there are two different types of aggression involved. One type, which behavioral scientists call "instrumental aggression", is forceful, behavior in the service of achieving some goal. This is the kind of aggression that manifests itself as daring, risk-taking, or seizing the initiative.

The other kind of aggression is expressive or reactive. A good many years ago, a group of behavioral scientists at the Yale Institute of Human Relations, made the basic discovery that "expressive" agression was a response to frustration. The idea was expressed then as "the frustration-aggression hypothesis" but it has subsequently been tested and found correct so often that it is now virtually a law of human behavior. (In fact, as Senator Moynihan has pointed out-[N.Y. Times Book Review, October 19, 1980]-the notion that frustration causes aggression is now so commonplace that hardly anyone remembers that it was once a controversial idea.)

This distinction between "instrumental" aggression, and "expressive" aggression is what directed and shaped the observational analysis of sports behavior. This example shows the power of a fundamental conceptual distinction to guide an applied study which then can make sense out of a confusing and obscure situation.

Why is there a "home court advantage"? The answer seems to lie in the social relationship between the crowd and the home players who draw from their supporters the encouragement and make daring moves--all of which are applauded. This useful aggressive behavior is encouraged. It is sharply different from the dysfunctional aggression exhibited by the visitors, which appears to be a reaction to their frustration at losing.

My next example is also about measurement but it takes us into a more esoteric realm: the relationship between psychological and physiologial states--which is right at the frontier of current knowledge. There is still a large area of mystery about how mind and body interact, but it is absolutely clear that people sometimes feel ill even though they have no detectable organic, physical disorder; and, on the other hand, some people with demonstrable organic pathology do not complain about feeling poorly, don't stay home from work, and apparently don't feel ill.

A striking example of the relationship between organic disorder and subjective feelings of illness was uncovered by a landmark study of an influenza epidemic at a military installation in New Jersey some years ago. Now, if I ask a medical dictionary what influenza is, I am told that influenza is "an acute infectious disease known since 1933 to be due to a virus". The average educated person also knows that flu is "fundamentally an acute respiratory disease...characterized by sudden onset of chills, fever, severe prostration, headache, muscle aches and a dry cough."

How do you know if you have influenza and not something else that produces similar symptoms? There are clinical laboratory tests that measure the presence of antibodies in the circulating blood, antibodies to specific viruses that have been typed, antibodies that signal the presence of infection.. The conventional measure for deciding that a person has an infection is a four-fold rise in antibody titer--a condition that has a very specific and concrete meaning in the laboratory.

Now, a person with a four-fold rise in antibody titer is infected but is that person ill? That is, does he/she feel ill, go on sick call, go to bed and stay there, not report for work and so on? The answer is: "Not necessarily".

In the study of a military base epidemic to which I referred, a team of physicians and behavioral scientists examined the individuals, their clinical laboratory test results, their medical histories, their work behavior during the epidemic and the results of certain psychological tests. The results are very interesting for they raise a fundamental question: what is illness?

The investigators isolated for special study two groups of workers at the base, all of whom showed the conventional organic sign of influenza, namely a fourfold rise in antibody titre. But one group felt ill, stayed in bed, didn't work, etc; while the other group reported for work, didn't complain of illness and carried on business as usual. What characteristics distinguished one group from the other? No available physiological measures, no hematological findings and no medical history items differentiated the two groups. But the individual's performance on a psychological test--The Minnesota Multiphasic Personality Inventory--did distinguish the sick from the not sick. In other words, in a sample of equally infected people, the ones who felt ill were only psychologically different from those who didn't feel ill. What is influenza anyway? And who has it? These are not sardonic, rhetorical questions but profound ones that go to the very heart of human experience, as well as to the very basis of medical diagnosis and treatment.

Once again, it is possible to ask the question because of the prior existence of a validated, systematically developed behavioral measure--one that came into being more than two decades ago for quite different scientific purposes. As in the other examples, this measure rests firmly on a psychometric foundation that came out of basic scientific curiosity about human behavior and the need for a reliable and objective way of measuring personality characteristics.

In my current field of work, medical behavioral science, there is a great deal of interest in pain and especially in pain control. Oddly enough, most of the work on pain control is quite recent. Pain is a very complex and not well understood phenomenon. Up to a decade ago, more or less, doctors tried to control pain by means of analgesic drugs or surgery. Even the best of these drugs (morphine) is, under certain circumstances, only a little more effective than a placebo or aspirin, while some psychological techniques can be quite effective. Surgical treatment of pain, even the severing of nerves, is chancy: sometimes surgery brings relief, often it makes no difference and sometimes, pain gets worse.

Part of the problem of pain is that the fundamental psychophysiology and neurology are not well understood. The nature and the distribution of pain receptors on the body, the nervous pathways that transmit pain messages and the nature of the biomedical messengers--all are obscure. There are some exciting leads now. Neurobiologists are working, with NSF support, to clarify the mechanism of action of certain peptides the hope that such understanding might lead to the development of biochemical "antagonists" to pain, that is substances which would block or slow the transmission of the pain message.

Such blocking agents are some distance down the road, so meanwhile, psychologists are working on the cognitive-emotional-motivational dimensions of pain and attempting to develop techniques for teaching patients to achieve some degree of self-control over pain. There are promising beginnings here and there--for example, patients can now be psychologically prepared for discomforting and painful diagnostic procedures, and there is some progress in the behavioral treatment of chronic pain sufferers. Hypnosis is effective in relieving pain under certain circumstances.

This area of research demands multi-disciplinary skills and knowledge for it is truly psychophysiological, biochemical and medical. It is also at the stage of development that so often characterizes the science of disease: the basic work is not so far advanced that there is a true scientific understanding of the phenomenon, yet the demand for intervention is so compelling that purely empirical measures are justified. Accordingly, work goes on at both the clinical level and the basic science level. Basic discoveries suggest to the imaginative therapist new strategies for treatment; while shrewd observations of patients detect events and conditions that influence the kinds of questions the basic scientist will address. This sort of work takes time. Neither an act of will nor a governmental mandate can close the gap between clinical practice and basic science. Only the persistent effort of scientists putting one block of knowledge next to another can build the bridge.

Another area of great scientific liveliness right now is linguistics and cognition--how children learn to speak, and how they develop the ability to think and to solve problems. There is a puzzling disorder of young children called "Turner's Syndrome" which is marked by physical deformity, moderate mental retardation in learning certain kinds of logical operations, numerical operations and temporal sequencing--all of which are thought to be related to language. Yet Turner's Syndrome children are reported to have normal language abilities. A better understanding of this anomaly might shed some light on how human beings learn to speak their native language--which is currently almost a mystery.

Another NSF project in the same general area is concerned with the study of congenitally deaf children. Many of them spontaneously develop a gestural system. They invent a system of communicative signs at about the same age that normal hearing children begin to talk. They do this despite having as little linguistic input as any human can have. Obviously, there is a strong human need to communicate lying behind this behavior, and there may be some innate structures. The scientific interest lies in discovering how this spontaneous signing behavior resembles or differs from the linguistic expressions of hearing children, on the one hand, and of deaf children who are allowed to observe conventional signing.

The sort of work that needs support by the National Science Foundation is basic development of the concepts and methods for getting an accurate and dependable quantitative estimate of numerous aspects of human behavior and the workings of the society we live in. My examples come from a small portion of the behavioral sciences because that's what I know best and can, I hope, explain most clearly. My intention is to show the connections between basic and applied work, between behavioral science and behavioral technology, and thus show what the value of behavioral science is and why it is worthy of support.

There are dozens of other areas in economics, sociology, anthropology, geography, political science, legal studies, and in other parts of psychology as well, where an experienced social scientist could provide equally compelling examples of worth, substance and accomplishment.

A body of social scientific work that deserves special attention and continuing support is the creation and maintenance of data resources. The social science programs of the National Science Foundation have taken the lead in fostering the establishment of computerized social science data archives which are accessible to research workers in all the disciplines all across the country and they are used. They are used to develop and test social and behavioral measurement techniques and mid-range theories of societal functioning. Data archives like these really serve two main purposes: they economically (by sharing access) extend the empirical base available to the individual investigator; and they provide both analysts and decision-makers with current information of relevance to public policy. It was the idea of establishing fifty years ago and continuously collecting serial data on economic performance that made it possible to have the economic indicators on which so many economic policy decisions rest today. Economists use these same serial data for research too. The parallel impetus to collect standardized series data on other aspects of society came very largely through a collaborative effort between the National Science Foundation and the Social Science Research Council. Again, the idea is to provide dependable quantitative signals about changes in the way our society is functioning. The expectation is that, when developed, these social indicators may be able to give advance notice of coming events in society that might be occasion for public policy actions. That expectation may not be realized for another 20 years, for the methodological problems are severe and, in longitudinal studies, only time will tell. But the data archives must be maintained, else the work of the last decade and more will be lost and all that investment wasted.

The legislative branch of the Federal government itself makes extensive use of social science. The General Accounting Office, for example, has created (under the stimulus of the Congressional Budgeting Act of 1974) its own Institute for Program Evaluation (on whose advisory Visiting Committee I serve). This Institute has the responsibilty for improving the technical quality of GAO assessments of government programs and for improving the Congressional use of evaluative information in its decision making. The techniques of program evaluation were developed by sociologists, psychologists and economists and the Institute is staffed by professional social scientists. I'd like to point out here again what sort of lead time is necessary for social research to be adopted and put to use. I myself did some almost pioneering work in program evaluation around 1950, but it was not until the late '60s or early 70's that evaluation studies became widespread and not until 1974, as I have said, that the Congress mandated GAO to conduct evaluations of government programs.

That figure, 20 years more or less, is probably not a bad estimate of the length of time required to bring a new idea, a new technique, a new method from the basic investigation stage to general use, at least in the social and behavioral sciences. That means, in effect, that the NSF is probably supporting today some research whose real usefulness cannot be known for two decades. Who can make the judgment now, today, with confidence that basic research is not worth supporting?

Surely the people best placed to make that judgment are the scientists themselves. The peer review system is the best means we have of judging how to choose the most promising research. That is not just my own opinion. I recently had the pleasure of meeting Dr. Bengt Gustafson, the former Secretary of the Nobel Prize Commi~~ttee. He~~ has given a great deal of attention to the question of why certain nations win much more than their share of Nobel Prizes--the United States especially. He has looked carefully into the data and has come to the conclusion that nations which depend upon peer review for evaluating scientific work do in fact produce the best and hence get the greatest number of Prizes. That is the only distinguishing feature of a nation's science that Gustafson can find to explain the differences--peer review. The lesson should not be lost on us. The best judges of what to encourage and what to eliminate in science are scientists themselves.

Let me close by calling your attention to a compelling statement about the importance of a better understanding of human behavior and its problems in a realm that seems to be completely technological: the nuclear generation of power.

John Kemeny, President of Dartmouth, and a distinguished mathematician, was chairman of the Presidential Commission to investigate the nuclear power plant accident at Three Mile Island. In a thoughtful, informative article in The Technology Review (June/July 1980), Dr. Kemeny writes about "the Lessons of Three Mile Island."

> " We started our work with the prior conviction that the big problem was equipment. But our overwhelming conclusion was that the basic equipment was amazingly good; it was the control room that was terribly designed from the point of view of the people who had to use it. The commission's attention slowly but steadily shifted, almost completely, from equipment to people. And we found that this was one of the most horrendous "people problems" we had ever encountered."

It is hard to imagine a better statement or a more eloquent argument for the support of behavioral science.

Mr. **WALGREN**. Thank you for that sound testimony; it is appreciated.

Dr. Glass?

[A biographical sketch of Dr. Glass follows:]

DR. DAVID C. GLASS

David C. Glass is Professor of Psychology and Director of the Laboratory of Biobehavior at the Graduate Center of the City University of New York, He received his Ph.D. in psychology from New York University in 1959, and did postdoctoral work in psychophysiology at the same institution. He taught and conducted research at Ohio State University, Columbia University, Russell Sage Foundation, Rockefeller University, New York University, and was chairman of psychology at the University of Texas at Austin. Dr. Glass is the current President of the Academy of Behavioral Medicine Research. He is author or co-author of over 75 papers and articles in professional journals and technical books. He is co-author of "Urban Stress: Experiments on Noise and Social Stressors," which won the AAAS Socio-Physiological Prize for 1971. He is also co-author of "Personality and Decision Processes," and "American Beliefs and Attitudes about Intelligence," and is editor of a three-volume series entitled "Biology and Behavior." His most recent book is entitled "Behavior Patterns, Stress, and Coronary Disease."

STATEMENT OF DR. DAVID C. GLASS, PROFESSOR OF PSYCHOLOGY AND DIRECTOR OF THE LABORATORY OF BIOBEHAVIOR, GRADUATE CENTER, CITY UNIVERSITY OF NEW YORK, AND PRESIDENT, ACADEMY OF BEHAVIORAL MEDICINE RESEARCH

Dr. Glass. I was asked to comment on what medicine has learned from the social and behavioral sciences, and since time is very short, I'll try to speak as quickly as I can on a rather extensive topic.

At the outset, two points should be borne in mind. First, many of the major health problems of this country, which are now chronic diseases—cardiovascular disease and the cancers are good cases in point—are influenced by psychological and social factors, including personal habits and lifestyles, such as smoking, diet, and levels of physical activity. These factors operate at the level of etiology and development of the diseases.

Second, once a disease has developed, behavior becomes important in its treatment and rehabilitation. Included here are problems relating to psychological aspects of pain and illness, as well as compliance with drug regimens, exercise, and dietary prescriptions. Also important in treatment and rehabilitation are problems relating to the interaction between patient and physician. We also must include in this category therapies aimed at altering a pressured lifestyle, along with behavioral therapies used in the rehabilitation of the physically handicapped.

My comments will be limited to the role of psychosocial factors in the etiology and pathogenesis of physical diseases. In developing this theme, I will give special emphasis to coronary heart disease. I do this because considerable progress has been made in this area over the last 5 to 10 years. Indeed, the role of behavioral factors in the cardiovascular domain is an exemplar of the biobehavioral approach to physical illness.

Before I discuss the linkage between psychosocial factors and cardiovascular disease, several definitions are in order. I call your attention to the fact that these definitions—and the measurement of the processes being defined—emerged from basic research in experimental psychology over the past several decades.

The first term to be discussed is stress, which can be defined with some degree of precision. There are two basic types. The first is systemic stress. This concept is associated with the work of Selye. It refers to disturbances of tissue systems; for example, a germ invading the body. Of more interest to us here is a second type of stress, psychological stress, and this may be defined as an internal state of the individual when he's faced with threats to his physical and/or psychic well-being. The individual, in short, experiences or anticipates some kind of harm.

The definition of psychological stress also includes an assessment on the part of the individual regarding his abilities to cope with this anticipated or actual harm. It is an imbalance between the two assessments—threat and coping resources—that leads to the experience of stress and the stress response, whether measured behaviorally or physiologically.

Now let's turn to possible links between psychological factors—in this case, stress—and physical illness. There are two main ways in which psychological stressors; that is, stress stimuli, may lead to ~~disease.~~ The first is major outpourings of neuroendocrines and related hormones which create changes in bodily processes and tissue function.

A second route by which stressors can produce physical disease is as follows: Stress often forces, or at least encourages us to engage in harmful living habits and activities; for example, trying to advance occupationally by means of a pressured lifestyle, including excessive cigarette smoking, poor diet, alcohol consumption, and poor personal hygiene. All of these habits have been linked to disease, and in the case of cigarette smoking, as many of you know, we're talking about a linkage to the three major sources of death in this country: cancer, heart disease, and stroke.

Let's turn to the relationship between behavior and cardiovascular disease. As many of you know, several decades of epidemiologic research has identified many of the risk factors for coronary heart disease. These include elevated serum cholesterol, cigarette smoking, special anomalies on the electrocardiogram, high blood pressure, et cetera. The interesting thing to note, however, is that the best weighted combination of all of these factors still accounts for less than 50 percent of the new cases of coronary heart disease.

What about the remaining 50 percent? It is this question that has motivated psychological and behavioral investigators to look for other contributing causes of cardiovascular disease. Psychological stress and a behavior pattern called type A are among the more promising psychosocial variables identified in recent years. Let us look at some of the evidence for a linkage between each of these variables and coronary disease.

Research by behavioral and social scientists have identified excessive work and responsibility as enhancing coronary risk, especially when they approach the limits of the individual's capacity for handling his work environment. Other job-related stressors include work dissatisfactions, particularly lack of recognition by superiors, poor relations with coworkers, and inferior work conditions. Other life dissatisfactions outside the work area—conflicts in the areas of finance and the family—have been correlated with the development of cardiovascular disease.

There is a large body of research linking the occurrence of traumatic life events with cardiovascular pathology. For example, one study has shown that survivors of heart attack have an increase in life changes during the period approximately 1½ years before attack, whereas healthy control subjects report a relatively stable number of life events during the same time period.

It appears, then, that a correlation exists between certain kinds of psychological stressors and coronary heart disease. However, the more important question is, How do we get from what is essentially outside the body—the stressors and the behavorial responses to the stressors—to a disease end-point? This question must be addressed from a biobehavorial perspective. I refer to a paradigm that, at once, includes physiological, behavioral, psychological, and social approaches to the complex problem of physical illness.

In the case of cardiovascular disease, we may ask: What is the nature of the physiological processes whereby stress enhances the development of cardiovascular pathology? Recent research has indicated some of these processes: One—and I do not have time to go into the data base supporting my statements—has to do with increases in traditional risk factors such as serum cholesterol and blood pressure as a result of psychological stress. Second, psychological stressors increase certain substances in the blood that many of you know of as adrenalin and noradrenalin. These substances have rather interesting consequences for the cardiovascular system, including acceleration of the rate of damage to the inner-walls of the coronary arteries over time. They also facilitate the aggregation of blood platelets, and that contributes not only to hardening of the arteries—the atherosclerosis that underlies so much of cardiovascular disease—but also to the formation of thrombi or clots, which are often at the basis of an acute heart attack. In addition, adrenalin and noradrenalin are believed, in some quarters, to precipitate cardiac arrhythmias which are involved in the phenomenon known as sudden cardiac death. Everyone is familiar with examples of this—the man who gets the clean bill of health in the physician's office and then goes out on the golf course and dies.

It would appear, then, that stressors, particularly via mechanisms involving neuroendocrines, have special significance as one of the risk factors for cardiovascular disease.

I have been emphasizing a linkage between psychological stress and a disease end-point. I have suggested some of the intermediary physiologic mechanisms whereby you can get from one to the other. Recall, however, that I included the notion of coping in defining stress. You cannot talk about the impact of a stressor without also talking about the individual's assessment of his ability to cope with that stressor. It appears that various kinds of coping styles may themselves be linked to cardiovascular disease. These coping styles can be viewed as complex lifestyles, and one, in particular, is the type A coronary-prone behavior pattern. In my view, it is a way of coping with life stressors. It may be effective in the short run, in the long run it is deleterious.

The type A behavior pattern consists of such characteristics as a competitive achievement striving, excessive time urgency and impatience, hostility and aggressiveness. It must be pointed out that these are not personality traits, but overt behaviors which are measurable with techniques currently available to behavorial scientists. The behaviors are elicited in susceptible individuals by appropriately challenging and/or stressful situations.

I think there is no longer any question, despite controversy in some biomedical circles, that type A behavior is a risk factor for a coronary disease end-point. I believe the NIH has included it in its list of risk factors.

The best data base for the type A clinical coronary disease relationship comes from a study in San Francisco, called WCGS, conducted by Meyer Friedman and Ray Rosenman. Again, I do not have time to go into that study. I should note here, however, that other research indicates that type A behavior correlates with the underlying disease process—coronary artery disease, or atherosclerosis.

Current experimentation is attempting to determine the physiological mechanisms by which one can move from Type A behavior to the disease end-point. Adrenalin and noradrenalin again seem to be important factors. Some of these data have been coming from my own laboratory over the last 3 years.

Two more points about cardiovascular issues, and I will move on to other diseases. In emphasizing the importance of psychological stress and coping, I am well aware of the fact that I am not telling the whole story, not even a significant portion of it. In the final analysis, coronary heart disease must be regarded as a multi-faceted disease, with a complex etiology and course of development. It is an illness that can best be understood, it seems to me, from what is essentially a biobehavioral perspective. This perspective has emerged in the last 10 or 15 years, and it is as much the result of efforts by behavioral scientists as by biomedical scientists. It is more than just a way of conceptualizing a problem; it includes a specific set of methods as well. In short, it is what we mean when we talk about a paradigm.

My discussion, has emphasized coronary heart disease as an exemplar of what I think medicine is learning from the behavioral sciences. However, it should be noted that the biobehavioral approach is making advances in other areas. We know that behavioral factors contribute to the development of infectious diseases. We heard some of that from Dr. Riecken. We have long known that they play a central role in psychosomatic disorders. Consideration of behavioral factors is a major feature of an emerging new field called psychoneuroimmunology. It has established, or at least has begun to establish interrelationships between the central nervous system, endocrine, behavioral and immunologic responses, which have implications for the etiology and pathogenesis of the cancers.

Each of the areas I have mentioned is discussed at greater length in one of the chapters in the NSF 5-year outlook entitled "Health and Behavior" written by myself and several colleagues. It is available to you, I am sure.

To conclude, I will make some brief observations on public policy implications of research in health and behavior. These implications include increased recognition of the importance of social and behavioral processes by both practitioners and the biomedical research community. Since many of our country's major health problems have their roots in individual behaviors, treatment and rehabilitation programs must be based, it seems to me, on data derived from controlled studies of the etiology and development of the diseases being treated.

And so it is research that explores the mechanisms integrating behavioral and biological processes that should be fostered. We are in dire need of investigators who are jointly trained in the biobehavioral disciplines. This demands increased science training, increased pre- and post-doctoral fellowships.

In my judgment, there is but one way to understand a problem such as cardiovascular disease. The investigator must be familiar with the range of biobehavioral skills and knowledge necessary to analyze the problem. Collaboration alone, while important, will not do the job. Unfortunately, we have never provided, in this country, for extensive multidisciplinary training and research facilities. This state of affairs antedates the philosophy of the present administration. I would like to see federally funded centers of research, perhaps located at universities, that focus on specific problems like cardiovascular disease, in which you bring together people with multi-disciplinary biobehavioral skills. That, in my judgment, would constitute a rational approach to biobehavioral science policy.

And that's where I will leave it.

Thank you.

Mr. WALGREN. Thank you very much. That's very constructive testimony.

Well, I think it probably would be best left where you have put it. As a panel, individually, together with the others, you have outlined very concretely the potential for this area that is proposed for a severe reduction I hope that when the committee as a whole looks at the record that you've developed here, there will be plenty of compelling justification for continued support in this area.

I personally appreciate your testimony very much. I wanted to ask Dr. Glass: How does exercise relate to stress phenomena, as you know it? Is it helpful?

Dr. GLASS. There is a great deal of debate on that question. Exercise does increase peripheral circulation and benefit heart action. Moreover, there is growing evidence—and this is all in the last 3 or 4 years—that it increases certain fractions of cholesterol, the high-density lipoproteins, which are thought to be beneficial, as opposed to certain other fractions.

Of course, as I often like to tell my classes, there is another way you can do that—with a daily ounce of pure-grain alcohol, which avoids jogging. [Laughter.]

Dr. GLASS. I believe on balance, that exercise probably plays an ameliorative role in the development of cardiovascular disease. It's long been accepted as an important part of any comprehensive rehabilitation program for heart patients.

Mr. WALGREN. Well, you know, you've made a strong argument for finite limitations on the terms of Congressmen—that they should be rotated out of here for their own good, if not the country's. [Laughter.]

Dr. GLASS. Perhaps.

Mr. WALGREN. Well, thank you very much. I appreciate your comments.

Dr. GLASS. Thank you.

Mr. WALGREN. In addition to the testimony today, we have a number of insertions for the record. These include Dr. Thomas Juster, professor of economics at the University of Michigan; Dr. Harvey Brooks, professor of technology and public policy at Harvard University; Dr. Ralph Andreano, professor and chairman of the department of economics at the University of Wisconsin; Dr. David Hamburg of Harvard University; Dr. David Grove, formerly chief economist for several major U.S. international corporations and currently president of the U.S. Council of the International Chamber of Commerce; The Association for the Advancement of Psychology; and

Dr. Arthur C. Gentile, executive director, American Institute of Biological Sciences.

[Whereupon, at 1:28 p.m., the subcommittee was adjourned.]

[The above-mentioned insertions follow:]

HARVARD UNIVERSITY
DIVISION OF HEALTH POLICY RESEARCH AND EDUCATION

HARVARD MEDICAL SCHOOL
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD SCHOOL OF PUBLIC HEALTH
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March 9, 1981

The Honorable Doug Walgren
Chairman,
Subcommittee on Science,
Research and Technology
U.S. House of Representatives
2319 Rayburn Building
Washington, DC 20515

Dear Congressman Walgren:

Pertinent to your hearings on the National Science Foundation, I would like to call your attention to Chapter 8 "Health of the American People" of the five-year Outlook on Science and Technology. It was prepared on request by the Office of Science and Technology Policy and the National Science Foundation. I was a member of the Steering Committee for the National Academy of Sciences/National Research Council that prepared the entire volume, covering Science and Technology broadly. Chapter 8 was prepared under my direct supervision and reviewed by the council of the Institute of Medicine as well as the governing board of the National Research Council. Therefore, I think it fair to say that it reflects a broad consensus on promising scientific directions pertinent to the health of the American people.

You will note that the biobehavioral and social sciences have an important place in this analysis. For example, advances in cardiovascular disease, some forms of cancer and mental illness depend heavily on advances in the scientific understanding of human behavior. The fund of knowledge from which health applications can be drawn is based in large part on fundamental research supported by the National Science Foundation. The United States has exerted dynamic leadership in support of the life sciences broadly conceived. This conception definitely includes the scientific study of human behavior as a major feature of living organisms. Our leadership in fostering the life sciences over a wide range of problems at a high level of quality has earned world-wide respect. It is now on the threshold of its greatest achievements. I believe that Chapter 8 illustrates one problen area in which these advances have great potential importance.

The outstanding achievements of the National Science Foundation in fostering the great work of the life sciences deserves the nation's fullest support.

Sincerely yours,
David Hamburg

David A. Hamburg, M.D.

HARVARD UNIVERSITY
DIVISION OF APPLIED SCIENCES

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March 9, 1981

The Honorable Doug Walgren
Chairman
Science, Research, and Technology
Subcommittee
2319 Rayburn House Office Building
Washington, D.C. 20515

Dear Congressman Walgren:

In conversations with your staff it has been suggested that I might comment on some of the changes proposed for the NSF budget by the Reagan administration, particularly as they may affect research in the social and behavioral sciences.

Before making these comments I should say something of my own background and interests, and my limited qualifications to comment on social science research. I am a physical scientist, trained as a theoretical solid state physicist, and until the late 1960s most of my research and practical experience had been concerned with the physical sciences and their engineering applications. I have been involved in the development of nuclear power in the early post war decades and later have been involved in the development of solid state electronics. Although most of my career has been in a university I worked for four years for the General Electric Company in the late 1940s, am currently a director of the Raytheon Company, and have maintained close ties with industry throughout most of my career. I have a strong interest in industrial innovation, and the impact of public policy upon it, and it is partly in this context that I am writing to you. Since the late sixties my interests have turned more and more towards the relationships between science, technology, and public policy, and since my retirement as Dean of Engineering and Applied Physics at Harvard in 1975, I have held an appointment as Professor of Technology and Public Policy and have devoted most of my teaching and research effort to this interface area, sharing my time between the Kennedy School of Government and the Division of Engineering and Applied Physics (recently renamed the Division of Applied Sciences) in Harvard University.

So little information is available on the details of the proposed budget cuts that it is difficult to make very specific recommendations as to the most appropriate Congressional response. Rather I shall confine myself to general observations which may be helpful in providing a context for Congressional discussion. In the present atmosphere of pressure to reduce all budgetary expenditures, it is difficult to defend any particular part of the budget without incurring the accusation of speaking for a "special interest." Nevertheless, in view of the strong national consensus that appears to exist on the importance of technological innovation to the future of the U.S. economy and even the U.S. political position in the world, we cannot afford to overlook any budgetary actions which might reflect adversely on this objective, even after granting that overall budgetary reductions may be essential for the reduction of inflationary expectations and the restoration of investment in productive activities as compared with speculation in appreciated property values.

In my opinion few items in the federal budget receive as careful scrutiny as basic science, or are subject to such careful planning and review by a wide variety of interests and from such a wide variety of perspectives. The basic science programs of the United States have evolved over a long period of years starting with the famous Bush report Science the Endless Frontier published in 1946. The national science budget has grown at varying rates, depending largely on fluctuations in overall national budgetary policy, but every year the allocation of funds between fields and among projects has been the subject of extensive study and discussion. During the late 1960s and early 1970s, for example, the Committee on Science and Public Policy of the National Academy of Sciences sponsored a series of studies of the status and needs of the various scientific disciplines; one of these studies was a review of the social and behavioral sciences which was conducted jointly with the Social Science Research Council.[1] I was chairman of the NAS Committee on Science and Public Policy at the time, and played a fairly large role both in planning and reviewing this very comprehensive report. In the process I received a liberal education in the social sciences, and became much more sensitive to the role that they could and should play in the development of science as a whole. I mention this exercise, however, as just one illustration of the amount of thought and planning that has gone over the years into the development of U.S. scientific programs. We have not arrived at our present allocation of resources among disciplines by an arbitrary or random process. Although any budgetary process is inevitably politicized in some measure, I believe the allocation of money for science is less politicized than most of the budgetary process. It has been a careful and considered process that has engaged some of our best minds and our most thoughtful people, and in consequence it seems dangerous to reject the outcome of this process by drastically cutting out selected parts of the program for reasons which, if press reports are to be believed, amount to little more than personal prejudice and hearsay on the part of a very small number of officials with no knowledge of the long background of thought and planning which has brought us to where we are today. To select the social and economic sciences for a 75 percent budget slash in a single year can only be characterized as foolhardy in my opinion. This proposal seems to have come from the Administration at the very time when many people in the Congress who have been especially critical of the social sciences in the past have just begun to have a better appreciation of their role and potential usefulness to our society.

I would not argue that all fields of science should be treated alike. One has to examine priorities in the light of all the factors available, not excluding the necessity for cutting the federal budget. But a cut in a single year which all but wipes out a whole broad area of scholarship for the sake of a budgetary saving that is almost "lost in the noise" seems unwise and unnecessary even in the light of all the stringencies that we undoubtedly face. It is certainly true that the benefits of social science research may be harder to quantify than in some other fields, nor do social science findings capture the imagination like some of the recent spectacular advances in the physical, biological, and geological sciences. But science is a seamless web to a considerable extent, with many invisible connections between apparently unrelated parts. Indeed this applies not only to science but to technology as well, and as I shall indicate below, social science knowledge may play a more important role in resolving our innovation dilemmas than is generally appreciated.

The author of a recent book on technological innovation in the newspaper publishing industry[2] has remarked that "innovation consists of skillful development plus social insight." History tends to record the "hardware" and we often forget that technological and social innovation often go hand in hand. In the early twentieth century the social dimensions of innovation were created primarily by the insights of inspired amateurs like Thomas Edison or Henry Ford with an intuitive insight into the needs and wants of society and the likely behavior of people. The United States was a pioneer in the systematic organization of the process of technological innovation, while the social part was largely left to gifted entrepreneurs, without benefit of any systematic social science, just as in most of the nineteenth century even technological innovation was carried out by individual inventors with little more than an intuitive or journalistic knowledge of relevant contemporary physical science. But I believe that situation is beginning to change rapidly, and that the scientific understanding of human behavior is going to be increasingly important as one of the ingredients of innovation. In other words innovation will be increasingly sociotechnical, not just technical.[3] Just as each new physical or biological technology has tended to be a little more "science-based" than the previous one, so I think that innovations of the future will likely have increasingly social-science-based ingredients. We already see this in the case of information technology, where its successful introduction often requires a systematic understanding of the social relationships within the organization in which it is going to be used. I believe we will less and less be able to afford a trial-and-error approach to the computerization of organizations, for example. There are already too many stories of the costly failure of ingenious information systems introduced without sufficient consideration of the social aspects of the settings in which they were supposed to operate. The very flexibility of information technologies as compared with the hardware or "hard-wired" technologies to which we were accustomed in the past provides a new positive opportunity for social innovation in the workplace which we need social science knowledge to help take full advantage of.

The above, of course, is only one example. Another example is the realization which is dawning on many people that a large part of the superior economic performance of the Japanese is not the result of superior innovation in the technological sphere, but rather the result of superior organization and managerial techniques which are more respectful of the motivations and perceptions of people.[4] Most of the Japanese successes have been based on more effective use of American technology. Perhaps this success was due more to the fortunate concatenation of cultural circumstances than any conscious superior use of social knowledge or insight; I would not want to pretend that the Japanese miracle is attributable to their better support of or use of social science knowledge. Nevertheless, it may take social science knowledge for us to understand the sources of Japanese success, and to determine what aspects of it are applicable in the sharply different American culture and traditions. The whole virtue of science, after all, is that, properly applied, it enables us to learn from the successes of others without having to imitate blindly and gradually discover by trial and error what works and doesn't work in our circumstances. When we understand why things work or don't work we are not condemned to retrace the entire learning processes of the pioneers.

In the United States, and throughout most of the industrial world, we are ambivalent about technical change. At one moment we are saying that technological change is too fast, and that society cannot keep up or adjust. Yet in the next breath we are saying that the only answer to our current dilemma is productivity, and productivity means technical change actually introduced into society. If in fact the only answer to our problems of stagflation and energy costs and shortages is the acceleration of technical change, isn't it also going to be necessary to accelerate acquisition of the insights that will enable our society to better adjust to technical change? I believe the time has long since passed when technological change can simply be imposed on people in the hope that they will simply adapt uncomplainingly. Modern economic activities are much more dependent on the voluntary cooperation of employees than was the highly disciplined factory of the early twentieth century. Rather social insights are required to anticipate the effects of change and to help design measures to ease adaptation and secure acceptance and understanding. I am not suggesting that basic research in the social sciences, such as is supported by the National Science Foundation, will provide the necessary knowledge directly, but I believe that the greater understanding that will derive from such research will form an indispensable background for designing the adjustments which will be necessary.

Perhaps a good example of our dilemma is the present sad situation in which the nuclear power industry finds itself. Here we have an important new technology that could offer a major part of the solution to the energy problem which this country and the western world face in the next two decades. And yet everywhere the installation of new nuclear power plants is in a state of paralysis, not, in my opinion, because of any basic technical difficulties, but because of a failure to anticipate the social, political, and psychological problems associated with such a novel technology and a failure to develop the institutional mechanisms which would give society confidence that the managers knew what they were doing. The lesson of the report of the Kemeny Commission was certainly that the failure at TMI was an organizational and educational failure, not a failure of technology per se.[5] The difficulty of such social failures, however, is that they tend to be much more irreversible than technological failures. It is much harder to restore social trust that has been lost, than to avoid losing it in the first place. In the coming technical revolution which the world will require to surmount the problems that it currently faces, these breakdowns of trust are likely to be increasingly frequent and costly unless we can improve our social insights. Admittedly this improvement cannot come from science alone, but I doubt either whether it can come from the uneducated intuitive political and social wisdom of entrepreneurs.

During the past two decades there has been extensive research on both the social and private returns to investment in technological innovation. Such research is subject to many uncertainties and caveats, but a surprising number of different methodologies have led to similar conclusions, namely that technical innovation is one of the principal engines of economic growth. Furthermore, there is considerable evidence that the social returns to investment in innovation are on the average almost twice as large as the private returns, i.e. that the benefits to society as a whole are about twice what can be captured by any private organization that invests in innovation for the purpose of long-term profit.[6] This means that there is what economists call a considerable "positive externality" associated with investment in innovation, as compared with other kinds of investments such as advertising or machinery or buildings. The existence of such an externality leads to the situation that reliance on private incentives alone leads to underinvestment in innovation, especially that part of the innovation process that lies nearest to the basic end of the spectrum. However, there are several kinds of research for which it is especially hard for private investors to capture the benefits, even though there may be considerable social benefits. Basic research is one example, because its results are public and its benefits spread in small amounts among many users whose identity cannot be predicted in advance. Another kind of research that is particularly resistant to private as compared with social recapture of the benefits is research that contributes to understanding of the impact of new technologies, both on the environment and on social systems. The examples of the nuclear industry, the chemical industry, the auto industry, and possibly the computer industry suggest that the industry itself does not invest in research oriented towards understanding its own effects on society until some striking and well-publicized (often exaggerated) incident leads society to impose regulations which force the industry to engage in an expensive catch-up program of research and development to satisfy often ill-considered regulations. It is these kinds of research that society itself must be supporting early enough in the game so that the kind of disruption due to unanticipated regulatory requirements that we have seen in the last few years does not occur. Instead the requirements imposed by society will be better known in advance so that they can be taken into account in design before large commitments have been made to a particular approach. The answer, in my opinion, is not for industry to lobby against regulation--which usually ends with expensive conflict and limited success--but to have research in place that anticipates the need for regulation before a big investment in a particular configuration of a new technology has been made. Clearly much of this research must be what we call environmental, but as we face new technologies such as the information technologies which could have large social effects, an increasing proportion of this research will have to be social and behavioral. To put the matter another way, I think there are increasingly positive externalities associated with social and behavioral research, and now of all times is a very poor time to be cutting back drastically on government support of such research, or any other research whose social benefits are particularly large in comparison with its private benefits.

This is not to say that all social and behavioral research is as good as it might be. It is much harder to do than physical and biological research, much greater controversy surrounds most of its conclusions, and it is harder to avoid unconscious biases dictated by hidden or explicit policy preferences of the researchers than is usually the case for the natural sciences or even engineering. But we must appreciate that people and societies are enormously complex, and social research is much younger than research in the natural sciences. We cannot now, and perhaps not ever, expect the broad generalizations and comprehensive insights that have been achieved in almost all the natural sciences during the last two decades. There will probably be more false leads and blind alleys, always. But it seems to me this should be an inducement for more not less effort.

Sincerely yours,

Harvey Brooks

Harvey Brooks

HB:km
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STATEMENT

OF DR. F. THOMAS JUSTER

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I appreciate this opportunity to present a statement on the budget recommendations relating to the social science programs of the National Science Foundation. Those recommendations, as I understand them, are for a reduction in the budget for the Social and Economic Science Division from a Fiscal Year 1980-81 level of approximately $34 million to a Fiscal Year 1981-82 level of $10 million, with reductions in other NSF social science areas of somewhat smaller proportions.

A reduction of that size in federal support for basic research in the social sciences will barely enable the NSF to meet commitments that it has already made. It is equivalent to a judgment that the social sciences do not warrant continuing support from public funds.

The budget recommendations in this area cannot be justified on any reasonable assessment of costs and benefits. The costs are well-defined; the problem is to define and evaluate the benefits.

There are at least three arguments, one primary and two secondary, for strong opposition to the recommended cut in the budget for the Social and Economic Science Division of the NSF.

The primary argument is that the payoff from social science research has been substantial in the past, and promises to be larger in the future: the resolution of many of the most important issues now confronting the society requires a better understanding of how the society works and how individuals and groups are likely to respond to changing conditions. To achieve that understanding, investment in social science research is a necessary precondition.

Secondarily, the long-run vitality of any society depends on the quality of its major research institutions, and in the social sciences that means the major research-oriented universities. The proposed cuts will significantly damage every major university in the United States.

Finally, society needs to attract its best young talent into a balance of occupations that represent important national priorities--business, science, education, the arts and humanities, etc. The virtual elimination of the social science part of the NSF will send an unmistakable signal to any budding young scientist--stay out of social science.

The beginning of the 1980s finds the U.S. beset with a number of serious economic and social problems: a lagging growth rate of productivity; a stubbornly intractable inflation rate; a public sector deemed to be too large (by many) and ineffective in achieving its objectives at reasonable cost (by more); a clearly foreseeable increase in elderly dependency, which will begin when the baby boom cohorts reach retirement age; unintended changes in values relating to marriage, family and children; a work ethic that many think to be eroding; and so on.

Public policies which affect these and other problems have to be formulated whether or not the consequences of such policies are fully understood, and whether policymakers are favorably or unfavorably inclined toward an activist role for government: accurate knowledge of the short- and long-term consequences of different alternatives is a prerequisite for effective policy formulation regardless of one's policy objectives.

I suggest that the most important knowledge gap that we have is in understanding both aggregate and individual behavioral responses to changes in economic and social conditions, and that reducing our ignorance about such responses is an important priority for the Administration and the Congress.

The links between research, increments to knowledge and the eventual returns to society are often obscure, despite the occasional dramatic example. In the social sciences, the returns are often impossible to quantify even when the research has a well-defined application. For example, society clearly benefits from the existence of the National Income and Product Accounts, the Input-Output structure of the economy, econometric models, learning and decision-making theory and models, and information theory and models: the value of these developments is attested to by the award of Nobel prizes to those involved in their development. We could not fashion public policies without knowing the distribution of earnings among the population according to various personal and other characteristics, or without continuing estimates of unemployment and underemployment. And we would benefit a great deal from knowing how much a one percent increase in gasoline prices would reduce gasoline usage, or whether the Social Security system increased or reduced private saving and by how much, or the relation between the severity and speed of punishment and criminal activity. But there is no simple way to measure those benefits or potential benefits.

Much social science research is concerned with insuring that policymakers have relevant knowledge about societal conditions and behavioral responses to existing conditions or programs. For example, it is important to know whether a program like Head Start actually increases child development and by how much at what costs, whether and how much older people tend to dissave when they reach retirement, what economic, family and locational factors are important in retirement decisions, whether the ratio of black to white wage rates is different for younger cohorts than for older ones, by how much productivity growth would be improved by a higher investment rate, how expectations about the rate of price inflation are formed, etc. Such knowledge surely facilitates the formulation of better public policies, but that does not enable us to say much that is helpful about the amount of social science research that the society "ought" to support.[1]

Besides the fact that measuring the payoff of research is complex and subtle, there are other characteristics of social science research which make judgments about the optimum level of public support difficult to form. Basic research is a high-risk enterprise: the overall return is the result of adding together a few activities that generate extremely high returns with a great many that generate little or no return. And, the knowledge and productivity gains from research activity are widely diffused, sometimes appearing at times and places distant from the original research objective.[2]

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[1] In all societies, most basic research activities are subsidized, typically by the central grovernment. The reason is a simple economic one--few business firms can capture enough of the benefits from the generalized knowledge that is the product of basic research to warrant undertaking such activities for profit. Yet all businesses depend on such research.

[2] An example may be useful. A study designed to measure the nonmarket activities of households uncovered the fact that the conventional estimates of labor market hours were a severely biased estimate of actual hours worked, suggesting that part of the widely discussed decline in labor productivity may be a simple artifact of the way we measure labor inputs in the productivity calculation.

Even though it is difficult to trace the research-productivity linkages directly, there are two types of indirect evidence that bear on the issue. First, we know something about the differences among nations in policies toward basic research, and about differences among those societies in productivity growth rates. Second, we know something about the nature of the current problems facing U.S. society, and about the kinds of research activities that might contribute to the resolution of those problems.

Among modern societies, trends in the level of support for basic research tend to be positively associated with trends in rates of progress. In countries like Germany and Japan, basic research support has been growing relative to GNP throughout the last decade or so, and in those countries rates of economic progress have been better than elsewhere. In the U.S., basic research support has been declining, consistent with the relative decline in U.S. growth rates during the past decade. And although one should be cautious about drawing inferences, it is in fact true that social scientists from the U.S., and the insights based on their research, are heavily in demand in both Western Europe and Japan. U.S. social science is the clear leader in the industrialized world, and its products are highly valued--except in the Administration's budget recommendations.[3]

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[3] While consistency is not necessarily the most important characteristic of policy, I do find it curious that on the day after the New York Times carried an article describing the proposed budget cuts for the social science part of the NSF, one of my colleagues received a call from a staffer in the Office of Management and Budget requesting information that turned out to be obtainable only from a study of income dynamics that has been financed for some years by the NSF!

A number of recent discussions of the U.S. economy and society convey what I judge to be an accurate impression of the nature of the current problems facing the U.S. Simply stated, the idea is that our current problems are more behavioral than technological; that is, sluggish performance arises not from the fact that we have become laggard in some technological sense, but from the fact that the processes of translating new technology into decisions has become less effective. Three illustrations may be useful.

It is often argued that the U.S. productivity lag during recent years is in part a consequence of the fact that business decision-makers are unwilling to adopt major new technologies, which often require completely new plant facilities, because of the uncertainties produced by the regulatory environment and by the high and variable rates of price inflation. If so, that cannot be cured by enhancing the flow of new technology, but can only be remedied by understanding and then modifying the environment in which investment decisions are made.

Second, it is often alleged that part of the problem now facing the U.S. auto industry, relative to its Japanese competitors, is not due to the fact that the Japanese have more advanced technology in their production facilities, but that the Japanese style of management and organizational structure has produced significant advantages over the U.S. in terms of work incentives, quality control, etc. Moreover, Japanese industries have generally been more receptive than U.S. industries to basic social science research on organizational structure and behavior--research done in the U.S.

Third, it is instructive to compare the aircraft and nuclear industries, which took different routes with respect to the employment of behavioral scientists in the design of systems. The American aircraft industry relied heavily on behavioral scientists for the design of cockpits, guidance systems, control towers and so on. U.S. airlines have an extraordinary safety record. The American nuclear industry did not employ behavioral scientists in the design of control centers. These centers are now widely recognized as unsafe, and their design was judged to be the chief culprit in the Three Mile Island incident. That incident cost hundreds of millions of dollars and almost surely resulted in delays in the conversion to nuclear energy.

The returns from research in the social sciences are not only hard to assess in a rigorous quantitative way, but are also dependent on the actions of decision-makers, including the Congress. Knowledge about facts or relationships may exist but have no impact because it runs-counter to the preferences of the public or of policymakers, or because it lacks credibility, or because it is not certain but in dispute, or because it has not been communicated effectively to potential users, or because there is no way to make it operational, etc. Some examples may help:

> *We know that under many conditions decentralized decision-making and participatory management produces a more effective organizational structure than a centralized and hierarchical style, but most U.S. firms retain the latter.
>
> *We know that the distribution of long-term (permanent) poverty is quite different from the distribution of short-term (temporary) poverty, but government funds continue to be allocated on the basis of the short-term definition.
>
> *We know that first-dollar coverage of medical expenses, and the absence of cost-sharing by way of co-insurance, are almost certainly important reasons for the rapid escalation of health costs, yet both are typical features of health insurance plans.
>
> *We know that substantially higher gasoline prices will cut gasoline consumption sharply, thus reducing our oil import bill and making us less vulnerable to supply interruptions, but there

> is little support for higher gasoline taxes among policymakers, because they assume (possibly incorrectly!) that the public would not stand for such taxes. And it is argued that higher gasoline prices will hurt the poor, in spite of evidence that higher income people drive a lot more miles and that few low income people drive a long way to work.

Dozens if not hundreds of other examples could be cited. It is unclear why social science knowledge is less widely used than it might be. The basic reason may be the probabilistic nature of much of that knowledge, plus the fact that most people already have opinions about the things that social scientists tell them--often strong opinions--and they are not easily persuaded to change them. The solution is to improve the state of knowledge in the social sciences, making it more certain and therefore more credible. Cutting the NSF social science budget by two-thirds, or eliminating it entirely, would guarantee the opposite result.

One way to gauge the appropriate size of public support for the social sciences is to ask what problems currently face the U.S., and what research is likely to be needed to help understand and, to some extent, resolve them.[4]

> *There seems to be general agreement that inflation is the most serious problem facing the U.S. Proposed solutions to that problem abound, as do analyses of its causes and dynamics--there are dozens of each, and little in the way of established, supportable propositions. Unless one is willing to solve that problem without any concern for the social and economic costs of the solution, improved knowledge about both the economic and psychological dynamics of inflation is essential.

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[4] Much of the needed research I have described might seem appropriately funded by mission agencies. Such research warrants an important role in any agenda, but agency time horizons are frequently too short and jurisdictions too narrow for dealing with some of the most important problems. Any research that is in the mandate of another agency tends to be shoved over there, or worse, to fall between stools and be neglected.

*We are in the middle of a significant change in attitudes and practices related to the family, children and marriage. Both the nature of those changes, and their consequences, need to be understood.

*A massive change in the proportion of the population 65 and over will take place early in the 21st Century, and dramatic changes in the proportion of very elderly (80 plus) will be taking place during the next several decades. But we know remarkably little about the implication of those changes for aggregate savings, for the financing of capital investment, for the health-care industry, for the housing industry, and for the children of the elderly population.

*Productivity growth in the U.S. slowed during the 1970s to something like half the rate of the previous two decades. Was that a temporary aberration produced by the response to the energy situation? Was it a consequence of the inflation of the 1970s? Was it because we have poor (or inappropriate) measures of outputs, inputs, and thus productivity? I do not think we know, and it seems important to find out.

*Population has continually moved toward the sunbelt and away from the snowbelt during the last several decades, bringing with it shifts of political power and job opportunities, to name just two. Moreover, the cities in the snowbelt are uniformly in difficulty--they seem to retain a disproportionate share of the poor and disadvantaged, their income base tends to erode, etc. That set of problems is in need of more attention than it has received.

*The U.S. has a significant dependency problem, which may well be exacerbated by the way in which social service agenices interact with welfare clients. The bureaucratic tendency of welfare agencies is to erect barriers for clients that are hard to surmount but, once overcome, tend to keep welfare clients in the system. Thus the bureaucracy itself may tend to play an important role in creating long-term dependency.

*It is widely thought that a higher rate of saving and capital formation would be desirable change in the U.S. economy, and numerous suggestions to increase the rate of personal savings have been advanced. Unfortunately, we have almost no reliable information about the distribution of actual savings among the U.S. population, and virtually anything can be "proven" with analyses restricted to data on aggregate saving for the population as a whole. It is difficult to form sensible national policies in which one can have confidence under those circumstances.

*There is a good deal of discussion about barriers to innovation in the U.S. economy. But most of what we know about that subject is speculative and impressionistic, and possibly self-serving as well. A serious study of the process of diffusion of innovation, of factors that inhibit innovation and change, and of policies that could facilitate innovation and change, has barely begun.

*We know that more older people will be living to more advanced ages in a society where, when older people need care, the only alternatives seem to be 24-hour care by an aged and overburdened spouse or prohibitively expensive nursing home care. The quality of people's lives would be improved, and the cost to society reduced, by the development of cooperative self-help arrangements. But these arrangements must suit people, leaving them a preferred amount of privacy, independence, and control over their own arrangements.

This list of issues where the social sciences can help inform policy essentially represents a partial collection of issues that have been of concern to a subset of my colleagues at the Institute for Social Research. It is obviously very far from a comprehensive list, since we represent only a tiny fraction of the social science community. While it cannot be used to specify how much public support ~~there~~ should be for social science research in general, it does suggest some of the reasons why a drastic cut in the level of publicly supported social science research would be a major step in the wrong direction.

An important contribution of social science research is to inform policy debates in the public sector--will proposed policies work in the way that proponents argue, do they have have negative by-products that outweigh the positive effects, etc. For example, the Administration seems to be arguing that the rate of personal savings can be measured by improving savings incentives via an increase in the real interest rate earned on savings. While that may be a desirable objective, the evidence that savings rates will respond to interest rate incentives is virtually nil--while there is some dispute about it, and while the world may be different now than it was during the 1950s and 1960s, the weight of the evidence suggests that consumers will not increase saving in response to increases in real return.

On the other hand, social science findings clearly indicate that an effective way to increase the rate of personal savings would be to reduce consumer incentives to acquire houses, cars, and other high-cost items that are usually purchased on credit: while savings may not respond much to increases in the real returns on assets, consumer borrowing will clearly respond vigorously to a sharp change in either the cost or availability of mortgage and other consumer credit. Thus there may be more to be gained in the way of an increased saving rate by such devices as reducing the preferential tax treatment of owner occupied housing than by any change that could be envisioned in the return to savings.

An area in which social science can be enormously helpful to policymakers is in evaluation of the impact of various public or private programs. Within the private sector, for example, a number of people at ISR are now engaged in an attempt to assess the contributions to organizational effectiveness of changes in incentives and in the way that decisions are made. Within the public sector, we are engaged in an assessment of the civil servant reform act. And more broadly in the public sector, many social scientists are involved in evaluations of major programs designed to accomplish objectives like enhancing early childhood development among the disadvantaged, improving the efficiency of the courts or of police systems, assessing the effect on the housing stock of incentives to repair and maintain housing in transition neighborhoods, examining the effect of guaranteed income systems on work incentives, etc. Inventing innovative and useful programs is important, but systematic evaluation of which ones work and which ones don't is equally important. For both purposes, the social science research community is indispensable.

Better social science can reduce impositions of government on people, by finding environmental arrangements that encourage them to solve their own problems. The failure of most social "experiments" to find much evidence of change is testimony to how little we know about complex human beings, and how difficult changing anything really is. There is a vast distinction between trying to manipulate people, as some experiments seem to be doing in the process of trying to understand them, and trying to discover ways of facilitating what people want to do by widening perceived opportunities. The one-motive theories of behavior implied in a great many public policies, ranging from accelerated depreciation to the determination of welfare benefits, are clearly inadequate to explain how the society actually works.

The Committee should keep in mind that public support for basic social science research has already been sharply reduced, in real terms, for the past half decade. Most such research is done in university settings by academic scholars: during the latter part of the 1970s, federal government support for social science research at universities has been roughly constant in dollar terms (at about $130-140 million); over the same time span, in comparison, federal support to universities for physical science research has almost doubled in dollar terms (to about $1.7 billion in 1978). Thus basic research support to social science from the public sector is now down to about seven percent of total basic research support, and has been declining sharply in real terms.

The importance of the type of social science research supported by the NSF needs to be understood. The typical project supported by the

NSF is of modest size, is dominantly concerned with basic conceptual or theoretical development, and is granted only after an intensive peer review process that screens out a great many meritorious proposals.[5] Another, and equally important, part of NSF social science resources goes to the design, production and distribution of data bases that emerge from the conceptual and theoretical work. These data bases provide the raw material for the testing and refining of hypotheses, the discovery of unexpectedly interesting distributions and relationships, and the development and refinement of statistical methodology.

As in other areas of science, the social sciences depend for their development on a judicious mixture of conceptual/theoretical work and the measurement of empirically relevant phenomena. But unlike the physical sciences, where the data are almost always generated by researchers and guided by theory, social science data are often generated by the administrative needs of the nonscientific world (the receipts, payrolls, tax payments or inventories of business firms, the enumeration of the population in the Census, the invoices collected for export or import recording purposes, etc.) or by the administrative or intelligence needs of governments (the National Income and Product Accounts, the payment of Social Security benefits or taxes, the characteristics of the housing stock, the number of prisoners in jails, the number of people receiving AFDC payments, the prices of consumer and producer goods, etc). These types of data are enormously useful for analysis of a great many types of economic and social phenomena. But they are an imperfect substitute for data tailored to the needs of social science researchers, guided by the concepts and theories of their disciplines, and designed and generated by the researchers themselves.

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[5] A review of the NSF basic research programs indicated that relatively more meritorious projects could not be funded (because of budgetary limitations) in the social sciences than in the physical sciences. See Social and Behavioral Science Programs in the National Science Foundation, Committee on the Social Sciences in the NSF, National Research Council, National Academy of Sciences, 1976.

The generation of nationwide social science data is expensive. In the physical sciences, the particle accelerators and telescopes that are basically devices for the generation of scientific data require massive investments of public funds. And in the social sciences, the cross-sectional and longitudinal surveys that provide data on both households and business establishments also require investments of public funds that are large relative to available resources.[6]

Given the large resource requirements of scientific data collection, the importance of basic theoretical and methodological work, and the potential for use of administrative data as a substitute for some research purposes, a budget cut for NSF supported social sciences of the recommended size would almost certainly eliminate most large-scale scientific data collection. Whatever the past successes or failures of the social sciences, virtual elimination of the data bases generated by social scientists for research purposes would guarantee a retardation in the rate of knowledge growth about society. A decade from now, both the Congress and the Administration would regret that decision.

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[6] The following describes three examples of important data-based research activities that are ongoing at the ISR. The Panel Study of Income Dynamics (PSID), now in its 14th year, generates a unique longitudinal panel on individual and family income which is used for analyses by hundreds if not thousands of social scientists, and by many public sector participants in the policy process. The PSID costs over $1 million annually, and is partly supported by the NSF. The National Election Study has been the basic source of data on the political behavior and attitudes of the U.S. population for over two decades, and is used by most quantitative political scientists in the U.S. and by most quantitative analyses of political affairs; costs currently run close to $1 million annually, and the data base is entirely supported by the NSF. And continuation of the time-use data base, a set of measurements focused on the nonmarket activities of households that began in the mid-1960s, is now under NSF review at a level of roughly $0.5 million annually. Scores of other examples, both at ISR and elsewhere, could be cited.

Summary

In an Administration committed to getting the society and the economy back on track by encouraging investment and saving and reducing wasteful public sector activities, policies designed to encourage the generation and eventual application of new knowledge warrant a high priority. Many of our societal problems are not technical or engineering ones but behavioral and organizational: it is this array of problems that needs to be better understood if we are to be successful in revitalizing the society. Seen in that light, the recommendation to cut the NSF basic social science budget from $34 million to $10 million, as part of an effort to reduce the size of the federal budget by $40-50 billion, is a bit like a recommendation to start slimming down an overweight giant by first removing his eyes and ears: it is a heavy price to pay for a small gain, and the benefit/cost ratio is adverse.

A Statement On
The National Science Foundation
And Basic Research in Economics

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For the past two decades, the National Science Foundation has provided much of the support for basic research in economic science. That research yielded a stream of discoveries that has changed the way decisions are made in both government and private business. While other agencies support research that applies the tools of economic science to practical problems, it is the National Science Foundation that provides support for the fundamental methodological work that leads to the development of new tools.

Economic science matured in important ways in the 1970s. Evidence of that maturity is seen is the application of sophisticated economic methods in many daily decisions by businesses, banks and governments. These methods, which are now a required part of the curricula of business schools and public policy schools and which are available even in law schools and medical schools, were derived directly from the basic research results of economists of earlier decades.

Developments in the analysis of uncertainty, in econometric estimation, in experimental design and in forecasting that were financed by NSF in the 1960s provide the basis for efficient decision-making today in the form of cost-benefit analyses, capital asset pricing decisions and public utility rate decisions.

Research in the 1970s has continued to yield a stream of important, fundamental discoveries that are only now beginning to be applied but that seem to be of great practical significance in these early applications. Among these discoveries are developments in game theory and bidding strategy that are now being applied in procedures for offshore oil lease auctions and in the efficient allocation of landing rights in crowded airports; in the understanding of how expectations influence the effectiveness of macroeconomic policy; in the ability to analyze and predict qualitative behavior (such as the decision of a teenager to work); and in analyses that deal formally with unobserved variables such as the native ability of individuals; or again, the expectations of inflation.

While these breakthroughs of the 1970s will improve the quality of public and private decision-making in the 1980s, the field remains fertile for further developments. Large-scale data bases are now becoming available, computer capacity is ceasing to be a computational constraint and the technical economic literacy of research staffs in business, government and the universities is growing. Therefore, new methodological developments in economic science are even more apt to be welcomed by a body of able practitioners in the future than in the past, even if these developments are quite complex and mathematical, as they no doubt will be.

Progress in the quality of decision-making in the 1990s depends to a large extent on the developments that are made in abstract economic science in the 1980s. It is this program that the National Science Foundation has supported in the 1960s and 1970s and that we feel has demonstrated that it deserves to be continued.

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*My colleagues, Professors W. Lee Hansen, Robert Lampman, Donald Nichols and Michael Rothschild assisted in the preparation of this statement.

Brief Examples of Basic Research

Supported by the National Science Foundation

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1. The methodology of economic model construction and economic forecasting (now a multi-million dollar industry) was worked out by economists with National Science Foundation funding.

2. Qualitative variables are ones which can assume only a few discrete values. Examples are employment status, mode of transportation and marital status. Econometric models were originally designed to discover the interrelationships among continuously varying variables (like unemployment and the price level) and could admit qualitative variables uneasily, if at all. Over the past decade econometricians (many of them supported by the National Science Foundation) have discovered how such variables may be introduced easily and comfortably into econometric models. All who use econometric models (and this includes most government agencies, businesses and private researchers) have benefitted from these advances.

3. Methods for analyzing problems with unobserved variables have been developed. Models incorporating these unobserved variables now provide useful information to policy makers in several fields. Examples include expectations of inflation or the differences among individuals in native ability or in initiative and willingness to work.

4. Economic theorists, supported by the NSF, have been trying to understand how auctions, committees, elections and similar processes work and when they should be used. This research has led to proposals (some of which have been implemented) for changing the rules by which offshore oil leases are auctioned, the techniques by which public television stations choose their programs and the procedures by which landing rights are allocated at such crowded airports as National and O'Hare.

5. Cost-benefit analysis is the technique which analysts in government and industry use for deciding whether or not particular projects should be carried out. While the basic framework of cost benefit analysis is straightforward and simple (add up the benefits of a project, subtract the costs; if the total is positive, the project is worthwhile), their application in any particular case is complex and difficult. The many theoretical and empirical problems which practitioners of cost-benefit analysis must face has advanced due to the work of researchers who were supported by the NSF. Questions which have been studied and resolved include: How should costs and benefits be measured in the presence of uncertainty? Does the tax system make it likely that projects which are unprofitable for any private enterprise are, nonetheless, socially desirable? How should benefits be measured when the effects of a program - such as increased life spans or less pollution - are not easy to price.

6. Many government programs and taxes have disincentive effects with respect work effort, saving and investment. This statement is the basis of what has come to be called "supply side economics". Basic theory and methods for measurement of these effects have been developed by economists with NSF funding.

7. The elements of modern financial theory have been developed by economic scientists whose basic research has been funded by NSF.

*My colleagues, Professors W. Lee Hansen, Robert Lampman, Donald Nichols and Michael Rothschild assisted in the preparation of these examples.

STATEMENT OF

THE ASSOCIATION FOR THE ADVANCEMENT OF PSYCHOLOGY

and

THE AMERICAN PSYCHOLOGICAL ASSOCIATION

The National Science Foundation (NSF) performs a vital national function as the major source of support for undirected basic research in the federal government. It supports critical investigation in all fields of science including the behavioral and social sciences. NSF's biological, behavioral and social sciences (BBS) directorate has supported significant basic research in these areas, particularly on science problems that are neglected by the mission agencies in the federal government, or that fall in the cracks between those agencies. In the coming decade, many of the social and economic problems facing this country will certainly continue to plague us: low productivity, lack of educational achievement, inflation, an aging society, declining citizen involvement, an eroding work ethic, dissolution of families, just to name a few. It is crucial that policymakers at all levels of government have high quality and accurate information to use in approaching the necessary solutions. A primary concern of the behavioral and social sciences is developing information about the personal, governmental and social activities that influence the creation and continued existence of these kinds of problems. These secondary and tertiary investigations simply cannot progress without a solid primary -- basic -- research foundation.

It is important to have an overview of the scope and nature of the work currently being done through NSF support. An overriding characteristic of the policy problems facing us is their complexity. This is due to the usually large number of factors that combine either to pose the problem directly or to create the setting in which the problem can exist. The Foundation supports research on a variety of topics in which psychologists are involved, ranging from understanding the neural processes underlying behavior and involved in neurological and mental disorders, to human nutrition and to efforts to aid the physically handicapped. Emphasis is also focused on the chemical senses, developing model systems from the lower animals and studying development of behavior and the role of the central nervous system in information processing. The most socially-useful findings often come from projects that did not contemplate specific applications. Comprehensive and lasting practical improvements most often come from a solid understanding of the problem.

It cannot be disputed that there is a relationship between knowledge borne of basic research and later returns in productivity. But, the direct links are more easily identified in the physical sciences than in the behavioral and social disciplines because of the difficulty of quantifying or measuring behavioral and social phenomena. The following are concrete examples of ways in which research results are adapted and applied in widely disparate uses.

- AVIATION SAFETY

The field of aviation provides a number of examples of the application of basic behavioral research findings. Most notable has been the identification of a visual illusion occurring during night landings that was a major contributing factor to a series of fatal jet aircraft accidents. The result has been the elimination of a problem which had been measured not merely in dollars, but in irreplacable human lives.

The illusion could not have been identified were it not for years of basic psychological research on human perception and psychophysics. It was from basic questions raised in these two areas -- questions such as: "How do humans perceive their world?"; and "What are the limits of accurate perception?" -- that such applications emerged.

- PREDATOR CONTROL

Ranchers in California are using "taste conditioning" to control predators without harming valuable stock. Coyotes and wolves are fed mutton laced with lithium chloride to produce an unpleasant reaction. As a result, the predators are conditioned in one step to cease attacks on sheep, even though sheep have been preyed upon for generations. Estimates of savings in lost stock run to the millions of dollars.

These conditioning techniques were developed in the basic behavioral research laboratory by researchers who began with no foreknowledge that their results would be applied in this way. Rather, they were interested in the basic psychophysiological mechanisms underlying taste. The same techniques now are being modified for application to two additional problems that have personal, economic and social costs: drug-abuse and anorexia nervosa.

- SAFE CHILDBIRTH

The New England Journal of Medicine (September 1980) published an article documenting the effects of a supportive companion in the delivery room on the childbirth process. Results included shortened delivery time and fewer complications during delivery. Both are associated with reducing infant risk factors, lowering medical costs after birth, and decreasing mental retardation resulting from delivery.

That such a powerful behavioral intervention was studied at all can be traced directly to basic research in cultural anthropology. An anthropological study of 150 cultures revealed that, in all but one, a supportive family member or friend remained with a mother during labor and delivery.

- ECONOMIC FORECASTING

The Index of Consumer Sentiment is a behavioral predictor of consumer attitudes, and is widely recognized as an accurate advance indicator of turning points in the business cycle. As such, its use contributes to cost-efficient economic planning. The Index has been employed extensively in the United States and recently was adopted by the the Commission of European Communities (Common Market).

The Index grew from basic research on psychological theories of attitude formation. This research encompassed the issue of whether it was possible to obtain reliable and useful measures of people's attitudes and intentions. Only then was the usefulness of this area for economic research realized.

- PROGRAM EVALUATION

Evaluation techniques play important roles in the efficient design of federal and private programs and in the control of their costs. Evaluation procedures often are written in during the formulation of projects to determine whether goals are met, and so, whether money has been spent wisely.

Evaluation techniques emerged directly from the development of research methods in the behavioral and social sciences. These academic disciplines, because of such hard-to-control subject matter as social process and developmental changes, require sensitive assessment techniques to determine experimental outcomes. The result is perhaps the most sophisticated set of analytic procedures to be transferred to non-academic settings.

- EMPLOYEE SELECTION AND JOB PRODUCTIVITY

Research on personnel selection is an area that has saved government, its military, and private industry countless millions of dollars over the alternative of trial-and-error pairing of men and women with their jobs. In fact, a recently reported article indicates that increasing this research to further improve selection procedure would result in $90 billion added to the GNP each year (Journal of Applied Psychology, 1979, pp. 602-626).

This applied process has its roots in social science statistics, psychometrics, and most importantly, studies of individual differences. This research included studies of the dimensions on which people differed and whether measures of these differences would predict an individual's behavior in specific situations.

◦ HEALTH AND DISEASE

Biofeedback allows for the conscious control of what are usually automatic bodily functions, such as flow, blood pressure, respiration and heartbeat. The technique now is considered by many to be the treatment of choice in dealing with migraine headaches and insomnia, problems which result in enormous costs to American business and industry through employee absence and poor work efficiency.

Biofeedback emerged from behavioral research on theories of animal learning. The major question of that research was whether it was possible to condition responses of the autonomic nervous system of the rat.

The common theme running throughout this list of examples epitomizes the importance of basic behavioral research: important social and economic benefits often emerge from basic research for which there were no known applications at the time the research was conducted. In addition, waiting to conduct that basic research until "cures" were vitally needed would seriously delay reaching a solution.

Women and Minorities in Science and Science Education

Strong support in both these program areas is crucial to the healthy growth and development of the scientific community. The provisions of Part B of the current NSF authorizing legislation are designed to encourage women and minorities to pursue careers in science and also will increase the involvement of these groups in the policy-making processes of the Foundation. The science education program is designed as an inexpensive way to reach younger students and generate interest in the sciences. It also would increase the competence and familiarity with science subject matter of undergraduate science instructors. Without an adequate pool of talented and interested researchers, future research activities and productivity will decline. Additionally, bias and stereotyping in society place substantial constraints on the aspirations and employment opportunities of women and minorities. It is important to develop methods of countering these obstacles in society generally as well as establish equity for those groups within the scientific community. In order to achieve these goals it is essential that organizations and individuals specifically concerned with the advancement of women and minorities be involved in the policy-making processes at NSF. We hope you will continue to support the mandates of Part B.

Scientific Instrumentation

All too often, research is dependent on out-of-date or worn-out equipment. Our basic scientific equipment in some specialties, including some psychology specialties, is at least one, perhaps two, generations behind the state of scientific knowledge. Ample documentation about the condition of scientific instrumentation is available from a number of sources. You may wish to refer to the Smith and Karlesky report on the condition of academic research (1977, New York: Change Magazine Press), the Report of the National Conference on Health Research Principles (1978

National Institutes of Health; DHEW) and the ongoing NSF Advisory Council's task groups. All indicate that upgrading of equipment is not just a priority, but a national necessity. We share this view and urge this subcommittee to include support for this endeavor in its program priorities when reauthorizing the Foundation.

Conclusions

-- The National Science Foundation must continue its support of basic research in the behavioral and social sciences because of the invaluable contributions made in these disciplines to the study and solution of a wide range of social and economic problems that we face in the 1980's.

-- There is ample documentation of instances where the results of basic behavioral and social research have been successfully applied as solutions to common problems despite the fact that no applications were contemplated at the time the research was conducted.

-- Waiting until "cures" are vitally needed not only delays reaching a colution, but also would create a gap in the research talent.

-- Strong support of women and minority participation in science careers and in science policymaking is crucial to the healthy growth and development of the scientific community.

-- Upgrading of scientific instrumentation is not just a priority but a national necessity because out-of-date or worn-out equipment diminishes out endeavors to achieve the best research results possible.

The Psychological community strongly supports the basic research mission of NSF. If we can be of assistance to this Subcommittee in addressing the complex problems associated with setting national science policies, please do not hesitate to call on us.

Statement from

THE AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES

Submitted by Dr. Arthur C. Gentile, Executive Director

As the chief executive officer of the American Institute of Biological Sciences (AIBS), I appreciate having the opportunity to express the Institute's concern about specific items in the 1982 budget of the National Science Foundation (NSF). The Institute is a consortium of forty professional scientific societies, whose membership represents all of the major subdisciplines in biology.

As Americans, we are not unmindful of the economic and social consequences of uncontrolled inflation and the need to exercise budgetary restraint in an attempt to combat this problem. We are also aware of the numerous demands made upon the federal budget. Nevertheless, as scientists we feel obligated to urge the Congress and especially this panel to examine carefully the responsibilities that some would have the National Science Foundation abandon or severely curtail in its support of research and education in science.

Support of the best research and education in the sciences has been and must remain the central purpose of the NSF. It is becoming increasingly apparent that as the demand for engineers, scientists, and computer specialists increases in this decade, manpower shortages are likely to appear. Already there are shortages in such fields as petroleum and chemical engineering and computer science. These shortages are likely to spread to other areas as we embark upon research to provide alternatives to fossil fuels, minimize the hazards of toxic substances, develop more productive and post-resistant plants, explore the opportunities of the revolution in biology based on recombinant DNA and attempt to solve the world food shortage. In a survey of the technical manpower requirements of its 255 U. S. member companies, the Industrial Research Institute reports that 91% expect more scientists and engineers to be employed by their company in 1985 than in 1980; 90% expect more in 1990 than in 1985. For 95 companies that provided data, the combined total of new scientists and engineers needed from now to 1985 came to 54,000.

At the same time, in a recent report to the President, the NSF and the Department of Education warn that the U. S. is moving toward "virtual scientific and technological illiteracy" in the population at large. Despite the grave tone of this study, the American Association of Engineering Societies says that this report underestimates the growing crisis. Similar views have been expressed in independent studies conducted by the Science Education Center of the University of Iowa and the Southern Regional Education Board.

In view of our need for more and better science education, it is inconceivable that the federal support for science education in the 1982 NSF budget has been virtually eliminated. It is apparent that we shall face increasing difficulties in securing talented and highly trained minds for the professional disciplines unless we strengthen rather than abandon our efforts to improve science education at all levels. The minimum goals of our efforts in science education should be too:

(1) stimulate interest in science careers at the pre-college and college levels, particularly among women and minorities who are strikingly underrepresented in the scientific and engineering fields. The underrepresentation

of women in engineering and science fields is often attributed to lack of adequate training in mathematics. Efforts should be made to make materials and instructional strategies to increase the participation of women in mathematics widely available. As for minorities, the full-time graduate enrollment in doctorate-granting institutions of all minorities in 1979 was, as percent of total enrollment: engineering, 4.2%; physical sciences, 5.0%; mathematics and computer sciences, 4.9%; life sciences, 6.0%. At the same time, 43% of the enrollment in engineering, 24.2% in the physical sciences, and 30.2% in mathematical and computer sciences was foreign students!

(2) improve the teaching of science, particularly at the pre-college level, by research on innovative teaching techniques and the development of curricula which reinforce science and mathematics education in our secondary schools. At the secondary school level, the emphasis on basic skills appears to be associated with a decline in the numbers of students enrolled in advanced science courses. Only about one-third of the nation's high schools require more than one year of mathematics or science for graduation. Colleges and universities have reduced the number of these subjects they require for admission. If students

take no science or mathematics after their tenth school year, they have effectively eliminated science as a career.

(3) insure that teachers at the secondary school and college levels are kept up to date in their knowledge of science. This goal can be accomplished by supporting conferences and short-courses and giving teachers the opportunity to return periodically to colleges and universities for additional study.

(4) promote public understanding of science. Indeed, the increase in the number of popular science magazines and the success of television science programs indicate that the public is not only supportive of science education but thirsty for a knowledge of science. If the public is being asked to support science and all its ramifications, it should be provided an opportunity to learn what science is doing, how it is being done, and why. To the average American, science has become too arcane, and this condition must be remedied if we are to expect popular support for scientific endeavors.

President Truman said: "No nation can maintain a position of leadership in the world today unless it develops fully its scientific and technological resources. No government adequately meets its responsibility unless it generously and intelligently supports and encourages the work of science in university, industry, and its own laboratories."

The major scientific and technological resource of any nation is its trained manpower. With shortages of trained scientists already being experienced in some fields by universities and industry, with the prospect that these shortages will include additional fields in this decade, and with the apparent need for more and better science education to ameliorate this situation, it is vital that the NSF continue its mandate to support education in science and engineering.

The work of science is research, and in our country most basic research is conducted at universities. This system has proved to be highly successful, as witnessed by the many important advances in science made in recent years. For example, recombinant DNA research has resulted in the formation of a new industry, genetic engineering, which promises to provide the means of producing substances for the treatment of many of the most serious diseases of man as well as contributing to the economic welfare of the nation. But as the frontiers of science are moved forward, research gets more sophisticated and requires expensive instrumentation.

For almost a decade, equipment needs for university research laboratories have been neglected. Today, many university laboratories do not have the instrumentation necessary to conduct modern research. The need for equipment for research is so vital that the elimination of support for equipment in the 1982 NSF budget is difficult to understand. The determination of the NSF to equip and modernize research laboratories was not undertaken lightly but only after careful and intense study of the problem. We urge you to consider seriously authorizing the restoration of funds for this important undertaking.

To force the NSF to abandon or delay any of the activities discussed here will surely cost this nation dearly in terms of future scientific discovery and application, and ultimately in terms of industrial productivity and human welfare. With adequate support, science and technology can and will provide the solutions to many of our nation's, and the world's, problems.

STATEMENT BY
DR. DAVID L. GROVE
PRESIDENT
UNITED STATES COUNCIL
OF THE
INTERNATIONAL CHAMBER OF COMMERCE

The country is in a mood to subject all government expenditures to critical scrutiny, and to cut them wherever the expenditures are nonessential. This is as it should be.

I have heard that one of the areas under review by the House Subcommittee on Science, Research, and Technology is the financial support the National Science Foundation has been providing to basic economic research. It would be a grave mistake, in my opinion, to make any significant reductions in such support.

My reason can be stated quite simply. Congress and the new Administration currently are undertaking a restructuring of our national priorities, and are searching for more effective ways to achieve our national goals. If we are to be successful in these endeavors, we shall need to know as much as humanly possible about how our economy operates, and how we can both measure and diagnose our successes and our failures.

Yet, in many areas which will be a subject of policy initiatives, we really do not yet know enough to provide adequate criteria for policy determination and implementation. For example, the policies being proposed by advocates of "supply-side economics," and those being proposed specifically to raise the rate of growth of national productivity, lack an adequate factual and analytical base, in many instances.

With National Science Foundation assistance, much work is being done on these and other important subjects; it must continue, and even be accelerated. After all, what could be more costly to the nation than ill-conceived economic policies which could have been avoided if appropriate basic research had first been undertaken, or policies which could have been designed to produce much better results, at much less expense, if more knowledge had been available at the time they were formulated? Slashing National Science Foundation support of such research surely will have costly consequences.

Taking a retrospective view, it is evident that much of the economic analysis regularly conducted both within the Government and by private business and financial firms makes heavy use of the GNP, National Income, and Flow-of-Funds accounts. These were developed, some years ago, under projects sponsored by the National Bureau of Economic Research, which depends heavily on grants from the National Science Foundation for such basic research. Similarly, much of what is known about the history and causes of productivity has stemmed from the National Bureau's sponsorship of projects in this area. And these are only a few of the many examples I could give of the contributions basic economic research has made to better decision-making by the Government and in the business community, even though we often overlook it.

In short, intelligent national economic policy requires the best possible factual and analytical base. Notwithstanding that much has been accomplished, we still do not have as good a base as we are capable of having. While, under the best of circumstances, it will take much effort and time to realize the potential contribution sound economic research can make to effective public policy, there should be no slackening of efforts to continue the progress being made in this direction. Cutting the financial support of the National Science Foundation for basic economic research at this time would seriously retard the progress we need to make if public policy is to be determined increasingly by knowledge rather than by rhetoric and special pleading which have little or no underlying factual or analytical base. Any such fiscal "savings" would be false economy indeed, with very costly long-term consequences.

I hope these considerations will lead to the Committee's full support of continued substantial funding for basic economic research by the National Science Foundation, because the funds lost by any cutbacks could not be replaced from other sources, public or private.

1982 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

TUESDAY, MARCH 17, 1981

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcommittee met at 9:15 a.m., in room 2325, Rayburn House Office Building, Hon. Doug Walgren, presiding.

Mr. **Walgren**. Let us begin.

Welcome, Dr. Slaughter. We are glad to see you back.

Today is the final hearing before the subcommittee begins to mark up the bill authorizing expenditures by the National Science Foundation for fiscal year 1982.

We now have for the first time the full details of the President's proposed budget. This is the first opportunity to ask questions about these details.

Personally I am concerned about some of the major changes in the specific programing that are reflected in the President's new budget for the Foundation. We have already put some attention on the proposal to eliminate the Science and Engineering Directorate and important elements of the behavioral and social sciences. But there are other concerns as well.

These include, particularly, instrumentation for basic scientific and technological research. This has been a major concern for some years. Decline in Federal investment in major equipment over the past decade has led to clear obsolescence and decay of many university laboratory facilities.

Second, international cooperative S. & T. programs slated for a proposed one-third decrease over all programs with serious implications to U.S. foreign policy as well as the science community. Certainly our competitiveness in the international marketplace will depend substantially on the full flow of information and research supported by these programs.

Third, there is the women and minorities in science program. This was an area of particular concern to Congress in last year's authorization and certainly of continuing concern to the committee this year.

These are among a small group of activities that were eliminated or severely cut in the President's budget. Today will give us an opportunity to inquire into the real significance of these cutbacks and to form some opinion as to the priority levels of these and other programs.

We have a number of expert witnesses here to help us form these opinions, and on behalf of the committee we look forward to your testimony and we appreciate your time and effort in coming.

With that, why don't we proceed directly to Dr. Slaughter. Our first panel is again those close to the National Science Foundation. Dr. Slaughter, of course, is the Director of the Foundation. He is accompanied by Dr. Eugene Cota-Robles, a member of the National Science Board. Dr. Cota-Robles is a professor of biology and a member of the Biology Board of Studies of the University of California at Santa Cruz, and a member of the National Science Board since 1979.

We appreciate your coming, Dr. Cota-Robles.

And also accompanying Dr. Slaughter again is Dr. Donald Langenberg, Deputy Director of the National Science Foundation.

Welcome, and please proceed. We look forward to what you have to say to us.

STATEMENT OF DR. JOHN B. SLAUGHTER, DIRECTOR, NATIONAL SCIENCE FOUNDATION; ACCOMPANIED BY DR. EUGENE H. COTA-ROBLES, MEMBER, NATIONAL SCIENCE BOARD; AND DR. DONALD N. LANGENBERG, DEPUTY DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. SLAUGHTER. Thank you, Mr. Chairman.

Dr. Cota-Robles and Dr. Langenberg and I are pleased to have the opportunity to be here today. I might say that Dr. Langenberg is particularly pleased to be here today. Today is his birthday. [Laughter.]

Mr. WALGREN. Under other circumstances we would sing. [Laughter.]

Dr. SLAUGHTER. We are greatly appreciative, Mr. Chairman, to you and the subcommittee for the time you have devoted to important issues of the budget for the National Science Foundation.

This is a difficult time for all of us. We know that your responsibilities are many. We appreciate that you and members of your subcommittee have shown so much interest in NSF's programs, have expressed willingness to hear our testimony, and to discuss the various matters we have brought before you. Today is no exception.

You have asked us to talk about three specific topics. But let me begin by making a few general comments about the program of the National Science Foundation and the budget presented to you by the administration.

I want to make sure that I emphasize the importance of research in our overall program. We have talked about a number of aspects of our research program, but we have not talked a great deal about the core research activities of the National Science Foundation. They are really the heart of the Foundation, they always have been, and they will continue to be.

I indicated to you in our informal hearing that NSF receives more than 25,000 research proposals each year. These proposals are received from researchers with innovative ideas throughout the country. The researchers are looking for funds in order to do the important research contained in their proposals.

We are able to support somewhat less than half of these proposals. And we think that the programs we do support represent the heart of a successful and continuing outstanding program of science and engineering research.

As you can tell from reading our proposed budget, we have tried hard to protect this core research activity in the face of the overriding need expressed by the administration to reduce Federal spending. The proposed reductions brought before you, therefore, fall much more heavily on areas such as science and engineering education which are themselves important but do not fall within our core research program.

I want to point out to you, however, that core research has not escaped some of the cuts. Of the proposed $320 million reduction, $100 million is to come from education, but $220 million is to come from programs that we characterize as research and related activities.

The reductions proposed in the industry/university cooperative research program, the reductions proposed in research opportunities for minorities and women, and the reductions proposed for our experimental programs to improve the geographic distribution of research are in fact cuts in research support. And the cuts proposed in funds to support instrumentation and facilities affect the ability to do research.

The point therefore is that these reductions in spending are necessary in the current economic environment. We understand this necessity. We want to make sure that this committee understands that we have already reduced NSF's research effort significantly in meeting the President's target. And we urge you not to reduce this effort any further.

Second, I want to say something about the ocean margin drilling program which has been discussed in earlier hearings before the subcommittee.

The ocean margin drilling program is a scientific program; it is not a resource exploration program. Its predecessor, the deep sea drilling project, using the drill ship *Glomar Challenger,* has been and continues to be one of the most successful scientific efforts ever undertaken.

The program we are now proposing, using the *Glomar Explorer,* shows every indication of being a worthy successor. Neither I nor the National Science Board would support it if we did not think it would be so.

The oil companies that have joined with us do so because the companies have a great interest in the science that will result, not because they believe that the *Explorer* will find oil. We are aware that company officials are not being altruistic; they are also interested in the long-term interest of their companies as well as the Nation. We think, for example, the oil companies are acting no differently than those chemical industries that have supported the polymer centers at the Massachusetts Institute of Technology, and the University of Massachusetts, or those industrial organizations that support materials research.

We believe that the ocean margin drilling program is important. Even if we were unable to obtain support from the oil industry, we would argue that the program should be supported by the Federal Government. We understand, however, that that is not feasible in this period of budgetary stringency. Therefore we have recommended that the subcommittee support the program as we have brought it to you, including support from the oil industries.

The work that resulted from the deep sea drilling project, particularly the understanding of the theory of plate tectonics, has done a great deal to revolutionize the whole field of geology. If the same sort of fundamental discovery results from the *Glomar Explorer,* as we think it will, the big difference this time is that we will have been fortunate to obtain from the private sector half of the support for such a fundamental increase in our understanding.

We believe that the National Science Foundation must play a key role in forging a new set of alliances among government, industry, and universities in the cooperative support of research.

The ocean margin drilling program, we believe, is a perfect example of this new kind of cooperative effort. We have already reduced the program in fiscal year 1982 by eliminating funds to provide some long-lead procurement items; $4 million has already been eliminated.

We strongly urge that there not be further cuts, so that we can continue the planning and preparations for this important program.

Third, I would like to say something about NSF's cross-directorate programs. We have used this term simply to indicate that these programs do not fit easily into the disciplinary structure on which most of the Foundation's activity is based. Included in these cross-directorate programs were activities in research instrumentation, research facilities improvement, research initiation programs for women and minorities, and other similar activities. These programs have been proposed for elimination in the revised budget because hard choices had to be made. Again, we felt that the most important thing that we could bring before you was a budget which showed strong support for the core research programs.

However, these cross-directorate programs are important in their own right. Therefore, within the limited resources available to us we are going to try to pursue the objectives contained in each of these programs. We are not going to be able to do all that we planned to do, and we are not going to be able to do as much as we had anticipated. But it is important to us to move ahead to provide support for research instrumentation, to encourage minorities and women, and to strengthen research throughout all parts of the country.

Yesterday I met with the division directors and other senior staff members of the National Science Foundation to discuss with them the problems that we will be facing if we are required to perform some of these needed activities within the framework of the core research programs, I have challenged them and promised to work with them in identifying new and innovative ways to provide support for these needs.

Finally, I want to say something about basic and applied research. I want to emphasize our belief that basic and applied research form a unified whole and that each will benefit from close association with the other. We believe strongly that in the future the arbitrary and artificial distinction between the two will largely disappear. We are putting into effect a number of ideas that will help us, we believe, to move in that direction.

In order to make sure the Foundation is doing well in carrying out its responsibilities, partly as asked of us by the Congress, we are directing the establishment of a new coding system which will allow us to identify programs, whether basic or applied. This way we can do the important job of monitoring our activities and obtain, some measure of how well we are proceeding.

I have also directed that each division develop a plan for expanding the number of applied scientists and research users among their ad hoc peer reviewers. We are asking that membership on our advisory panels include applied scientists and, where appropriate, users of scientific research.

Finally, the National Science Board has established a subcommittee on the coordination and management of applied research to help us in monitoring the implementation of the changes that have been made and in identifying additional policies and procedures that may be necessary. We think that these initiatives are a move in the right direction, and that our new policy toward basic and applied research will work very effectively.

Mr. Chairman, I would like now to turn to the three topics that you asked me specifically to address: Women and minorities in science, international cooperation in science and technology, and research instrumentation.

First, women and minorities: The National Science Foundation believes that the continuing vitality and productivity of the Nation's scientific and technological enterprise depends on the full involvement of all talented and interested persons. We fully support the intent of the Science and Technology Equal Opportunities Act passed last year as a part of NSF's authorization for fiscal year 1981.

We believe that NSF has a special responsibility to help develop the research capabilities of persons belonging to presently underrepresented groups. In spite of the fact that we will have a reduced budget in these areas, we are going to meet some of the terms of the fiscal year 1981 authorization act. The funds provided in fiscal year 1981 for targeted programs for women and minorities are greater than those provided in fiscal year 1980, even considering rescissions.

For 1982, we plan to examine how women and minority scientists can best be encouraged through our ongoing research programs. After the act was passed in December, I decided that my office should take the lead responsibility for review and implementation of its provisions. A task group of representatives from each directorate was assembled to design programs, plan preparation of the reports, and establish the advisory committee called for by the act. That task group has been meeting and will continue to meet regularly.

On February 25 we established the Committee on Equal Opportunities in Science and Technology. We founded its charter with this committee and your counterpart committee in the Senate.

Early in January we sent a letter requesting nominations for membership on the committee to professional organizations within the scientific community and to organizations active in promoting equal opportunity for women and minorities in science and technology. We also asked and received recommendations from the National Science Board and from the Foundation staff. We received hundreds of nominations of highly qualified people to serve on these committees.

I have prepared recommendations which will be given to the National Science Board at its meeting later this week. As soon as I have received approval from the Board on the final list, I intend to appoint the members of the committee.

The committee will explore the nature of the barriers that may inhibit women and minorities from full participation in scientific and engineering research. I will also ask the committee to assist in examining how women and minorities can best be encouraged to send more proposals to the research programs of the National Science Foundation.

Mr. Chairman, I think we have moved strongly to follow the intentions of the Congress as expressed in that act. I think we all recognize the important benefit that this Nation derives from the participation of all persons who bring to bear their creativity, insight, and enthusiasm. I pledge my personal energies and those of the National Science Foundation staff to do all we can in this important area.

Let me move now to the international programs. NSF has for some time recognized the importance of facilitating links between scientists in the United States and scientists in other countries. We have two major program elements: international cooperative science, and international scientific organizations and resources. We also have a smaller program concerned with providing travel support for U.S. scientists who wish to participate in international scientific meetings.

The first major program, international cooperative science, supports specific cooperative projects within the framework of bilateral agreements between the United States and foreign countries. It also includes scholarly exchange programs with China, the Soviet Union, and Eastern European countries. The China program is particularly important, because it provides an opportunity for U.S. scholars to gain access to China, and it also has important foreign policy considerations.

The program with China has been protected against reduction in the revised budget. The Soviet cooperative program, on the other hand, has been greatly reduced. In 1980, $3.2 million were allocated for that program, and we believe it had a significant benefit for U.S. science. In the present climate, however, that program has been reduced to $400,000; the minimum level that we believe should be provided for that program. The National Security Council also has supported the program at the $400,000 level.

The second major element is the international scientific organizations and resources program. Two major organizations are supported in this area: the International Council of Scientific Unions, and the International Institute of Applied Systems Analysis. We are proposing that both of these program elements be eliminated in fiscal year 1982. U.S. participation in the International Council of Scientific Unions will continue to be supported by research programs within the Foundation. That union is actually composed of 18 international scientific unions, each of them focused on a specific discipline. Under the proposed budgetary plan, we are expecting each disciplinary research program in the Foundation to support its own union.

The other organization, the International Institute for Applied Systems Analysis, presents a more complicated problem. The United States and the Soviet Union are the principal supporters; 14 other countries provide fewer funds. The Institute has been a success both scientifically and as a neutral forum for communication between East and West.

In the present budget, however, we plan to terminate NSF support for U.S. membership. Under the charter of the Institute, the U.S. National Academy of Sciences is required to give a 1-year notice, effective in December, of our intention to resign. We may be required to continue support for U.S. participation during 1982. If, so, we will determine whether the funds necessary to carry on our obligation will be obtained from other programs or primarily from the bilaterals that I've already mentioned. The final decision will be made after we have consulted with our foreign partners.

Despite the cuts that have been proposed, we intend to maintain a vital and effective international program. Science always has been and always will be an international activity, and we have gained from the participation of U.S. scientists with their foreign colleagues. The cost is small, and the returns are great.

Finally, Mr. Chairman, I would like to address perhaps the most critical problem facing university science today: The present set of obsolete and inefficient research instruments. The work of science entails going further and further into the unknown. The advances in almost all disciplines of science and engineering depend upon the availability of new tools and instruments. Only with state-of-the-art equipment and facilities can we make the kinds of leaps in understanding necessary to further our country's capabilities in science and technology.

The state-of-the-art in modern research instruments moves ahead rapidly. Those instruments which were new and on the leading edge as few as 5 years ago, in many cases are obsolete today. Many university laboratories are no longer properly equipped; this is a major problem, because the product of university laboratories has a great deal to do with the science capability of this country. University scientists are not able to take advantage of the new opportunities for acquiring knowledge because of the poor state of their equipment and facilities.

Foundation program officers have been under great pressure recently to reduce the amount of support going to individual research groups or investigators. There are simply not enough funds to handle all the needed research activity being proposed. Consequently, there is often a natural tendency to sacrifice equipment, in order to make sure that the research group continues to have the funds to do its work.

We may be able to get away with this approach for a short time, but the problem simply gets worse as time goes on. It is difficult to quantify the magnitude of the problem.

A study was made and a report appeared in Science magazine recently, Mr. Chairman, describing the instrumentation needs of research universities. I would like to submit the report for the record.

[The report mentioned above follows:]

Instrumentation Needs of Research Universities

Laurence Berlowitz, Richard A. Zdanis
John C. Crowley, John C. Vaughn

Instruments are the tools with which researchers expand scientific understanding of the properties of nature. Their importance to the progress of science is indicated by the number of Nobel Prizes awarded for the development of instruments or methods of measurement. Within the past three decades, for example, Nobel Prizes in physics have been awarded for the discovery of nuclear magnetic resonance (NMR), the phase-contrast microscope, the transistor, the Cerenkov counter, the bubble chamber, the maser and laser, and holographic imagery.

Traditionally, research universities have played an integral role in the conception, development, and innovative use of instruments. For example, in 1928 Ernst Ruska, a beginning graduate student, began work on the first electron microscope. A half-century of development, based to a large extent on university research, has established the electron microscope as a powerful tool for the investigation of structure down to the atomic level. The development of instruments such as the flow cytometer has provided methods for conducting precise analyses of the chemical constituents of individual cells. As was true of the electron microscope, the flow cytometer was developed through a convergence of technologies.

Due to the rapid pace of instrument development, many instruments purchased only a few years ago are now obsolete. The 1960 Nobel Prize in physics was awarded for the development of the bubble chamber; today this technique has largely been replaced by electronic detectors such as drift chambers and wire chambers. F. Block and E. M. Purcell developed NMR in 1945 and 1946; enhancements of the technique (Fourier transform, signal-averaging methods, superconducting magnets) have produced an approximately 10,000-fold increase in speed and a 100-fold increase in sensitivity over the best equipment available only *10 years ago*.

However, the cost of many new instruments threatens to make them inaccessible to many university researchers. The cost of multinuclear, high-field NMR spectrometers is approaching $500,000; flow cytometers cost up to $175,000. But without such instruments, the capacity of researchers to work at the frontiers of knowledge would be greatly impaired, and opportunities to develop superior instruments and expand their uses would be lost.

To assess the present capacity of universities to acquire necessary instruments, the authors, under the sponsorship of the Association of American Universities, conducted a study for the National Science Foundation (NSF) on the scientific instrumentation needs of research universities. The study examined the current status of scientific instruments in major research universities and sought to identify factors that facilitate or impede their acquisition, use, and development.

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Summary. This article assesses the status of scientific instruments in major research universities and identifies factors that facilitate or impede their development, acquisition, use, and maintenance. Sixteen universities, six national and government laboratories, and nine commercial laboratories were visited; over 700 individuals were interviewed. Data on instrument acquisition and age were collected. Instrumentation was examined in physics, chemistry, biological sciences, earth sciences, and electrical engineering. The study found that the quality of university instrumentation has seriously deteriorated, due principally to a relative decrease in instrumentation funding, inflexibility within the project grant system, and insufficient support for maintenance.

Study Design

The project team visited 16 universities, six national and government laboratories, and nine commercial laboratories. Of the universities visited, eight are public and eight are private. Five public and five private universities were chosen from the 20 universities having the largest total federal R & D obligations in fiscal year 1977. Major research universities were emphasized because it was thought that this would identify the most critical national problems. To broaden the sample by rank and geographic location, six additional institutions were selected from universities with lesser R & D obligations in that year. National, government, and commercial laboratories were included to provide a context for assessing the university laboratories.

Working in close conjunction with a seven-member advisory committee of university and industry representatives, the project staff examined research instrumentation in physics, chemistry, biological sciences, earth sciences, and electrical engineering. In all, over 700 individuals were interviewed, including some 300 university researchers, department heads, and research administrators and approximately 60 researchers and research managers in national, government, and commercial laboratories. Numerical data on instrument acquisition and age were gathered from 14 universities and four commercial laboratories. Anecdotal data presented here were selected to be representative of the problems at major research universities. Where conditions were variable, the range of situations has been presented.

Major Instrumentation Problems

Instrumentation needs vary widely within and among the universities and departments we visited. Although this diversity makes generalizations difficult, six major problem areas were identified:

Table 1. Sources of instrumentation funding at universities visited (fiscal year 1979). The data are averaged over 68 departments and subdepartments at seven public and seven private universities.

Source of funds	Public (%)	Private (%)
Federal research grants and contracts	46	59
Federal equipment grants and contracts	14	19
Institutional sources	28	11
Capital construction funds	9	5
Other	3	6

1) *Acquisition and replacement*. University researchers are having great difficulty replacing worn-out or obsolete instruments and acquiring newly developed ones. Data from a major industrial research laboratory show that the total capital expenditures per scientist doubled from 1975 to 1979. In a recent study of the five important physicochemical subdisciplines, it was shown that the cost of scientific instruments priced above $5000 rose at an annual rate of 20 percent from 1970 through 1978, far exceeding the average inflation rate (*1*).

Table 1 shows that most university instrumentation has been purchased with funds from federal research grants and contracts. However, in some fields it has not been possible to adjust the size of grants to keep pace with steadily rising costs.

To sustain the scope of their work, researchers must spend large amounts of time competing for grants from many agencies, both federal and nonfederal. Active scientists often require three or four current grants to maintain their research programs. Many investigators report that, while in the past they were able to meet most of their instrumentation needs through research grants, the increase in all research costs, combined with the relative decrease in the size of research grants, has left them unable to purchase all but the least expensive equipment through their grants.

2) *Start-up funds*. New faculty members require start-up funds to provide the instrumentation needed to initiate a competitive research program. These funds are now difficult for many universities and departments to provide; while the costs to equip research laboratories are rising, institutional sources of start-up funds are shrinking.

Table 2 provides an example of increased start-up costs in chemistry. The table lists the actual expenditures of a midwestern public university for equipping two new faculty members, one in 1970, the other in 1979. Also listed are the major shared instruments to which they required access. Each researcher was working in the same general field and had the same level of experience (Ph.D. plus a 2-year postdoctoral fellowship). In addition, each had the same basic assignments (teaching and research) at the institution. Both sets of instruments were used to investigate the same general phenomena, but the 1979 instrumentation allows analyses to be made with much smaller samples, saving time and money; furthermore, the results are considerably more accurate and specific. Indeed, the specificity and sensitivity required to make contributions to this field would be impossible without the modern devices listed.

Inflationary price increases are simply the rising baseline upon which are superimposed the frequently much larger cost increases resulting from advances in existing instruments and the advent of new ones. The price increases shown in Table 2 are equivalent to an annual increase of 22 percent for laboratory instruments and 23 percent for departmental instruments. In addition, the 1979 instrumentation requires more support equipment for its proper operation and maintenance, adding expenses not reflected in the table. Clearly, instrument capabilities have increased dramatically, but so too have costs.

The capacity to meet these increasing start-up costs varies greatly. The chemistry department at one midwestern public university can provide up to $70,000 for new faculty members and considerably more to recruit senior researchers. However, administrators at a southern private university can provide only $10,000 to $20,000 a year in start-up funds for nonmedical researchers—although on rare occasions they have been able to generate as much as $100,000 by pooling endowment resources over 2 or 3 years. The highly ranked western universities that we visited vary widely in their ability to provide start-up funds. Some report no difficulties; others have very low ceilings. The chairman of the biology department at a western public university reports that when he joined the department 15 years ago as a new faculty member, he received $30,000 in start-up funds; today the department can provide only $10,000, even though costs to equip a laboratory have increased substantially.

3) *Operation and maintenance costs*. Meeting the cost required to operate and maintain instruments is a ubiquitous problem for university researchers. The operation and maintenance burden includes expenditures for service contracts for commercial instruments, replacement parts, staff salaries and equipment for support shops, and, of course, operating the instruments. A researcher at a midwestern public university recently purchased a $30,000 cryogenic magnetometer; to operate the instrument requires $8,000 annually, principally for liquid helium. As another example, plasma tubes for an argon-ion laser have to be periodically replaced at an average annual cost of $10,000.

According to the chairman of the chemistry department at a midwestern public university, operation and maintenance costs could be supported by other budgets in the past, but now the costs exceed the capacity of institutional funds to meet them. When departments cannot adequately meet operation and maintenance costs, instruments are improperly maintained, shortening their useful life; support personnel are cut back and support projects pile up; faculty and students function as technicians, with a consequent loss of time for research and training. Obsolete instruments may be more difficult to operate and more likely to break down; manufacturers may refuse to renew service contracts; spare parts may no longer be available. These consequences can cripple a research program.

4) *Facilities construction and renovation*. Without adequate facilities, research programs cannot operate at full capacity. In the 1960's, substantial federal resources were available for the construction and renovation of research facilities. However, such support has diminished in recent years, placing an increasing strain on institutional funds.

Frequently there is a long delay between the decision to construct or renovate facilities and the acquisition of the necessary funds. With today's inflation, this delay can substantially reduce what the funds can accomplish. At a midwestern public university, inflation has effectively eliminated $250,000 from a planned $2 million wing to be added to a bacteriology department building; at a western public university, the time it is taking to raise $4 million for a biology building will likely cost at least one of its four floors. At one eastern private university, a new biology facility vital to the strengthening of the department has had to be abandoned.

Aging facilities impede research efforts. Recently, a malfunctioning distillation system in the zoology department building at a midwestern public university paralyzed research in the building for over a week. At a private university in the East, a promising program in contraception research was abandoned because the university could not meet new federal requirements for housing the dogs used in the research.

Animal facilities, greenhouses, and herbaria are particularly difficult to maintain. These facilities, tied as they usually are to building construction, are becoming old, but replacement and renovation funds are difficult to obtain through federal grants and are becoming extremely difficult to obtain from local sources.

5) *Support equipment*. Support equipment is instrumentation not directly involved in the measurements performed in experimental research but necessary to test, calibrate, or provide an appropriate environment for the core instruments. It includes oscilloscopes, vacuum leak detectors, and power supplies.

Difficulties in funding support equipment often arise not because of the absolute level of support but because the funds are targeted for other categories. A number of researchers report that specialized research instruments are more likely to be funded than routine, but important, support equipment.

6) *Inflexibility of funding*. Research is an ongoing process that rarely has distinct boundaries or a specifiable future course. Yet many investigators report that research funding is becoming increasingly inflexible. There is increased pressure for fast results. More paperwork is required. When gaps in funding occur there are no reserve funds to sustain research programs; valuable support

Table 2. Increased start-up costs for research: example from synthetic chemistry.

1970		1979	
Instrument	Cost ($)	Instrument	Cost ($)
Laboratory instruments			
Two Rinco evaporators	300	Rotovac evaporators	1,700
Two vacuum pumps	400	Preparative liquid chromatograph with fraction collector	7,200
Spinning band distillation apparatus	825		
Three solvent stills	600	Analytical liquid chromatograph with recorder and data system shared with capillary column	13,250
Melting point apparatus	150		
Gas chromatograph and recorder	1,450	Gas chromatograph	11,300
Hot plates, stirrers, heating mantles	275	Solvent stills with fire safety hoods	4,500
Glassware	500	Hot plates, stirrers, and heating mantles	600
Infracord infrared spectrometer	3,500	Microware with standard taper joints	3,000
		Glassware	800
		Thin-layer chromatographic plates and tanks	1,500
Total	8,000		43,850
Departmental instruments to which access is needed			
A-60 NMR spectrometer	40,000	90-mHz R-32 NMR spectrometer	52,000
Cary 14 ultraviolet/visible spectrometer	14,000	200-mHz wide-bore NMR spectrometer	225,000
Hitachi RMU-6 mass spectrometer	60,000	CFT-20 carbon-13 NMR spectrometer	80,000
Precision refractometer	2,500	Finnigan 4000 mass spectrometer and data system	160,000
		Cary 17 ultraviolet/visible/near-infrared spectrometer	32,000
		Digilab FT-infrared spectrometer	82,000
		High resolution mass spectrometer CEC-21-110	110,000
Total	116,500		741,000

personnel must often be laid off and may be irretrievably lost when such gaps occur.

A geologist at an eastern private university feels that peer review boards, operating under current constraints, fund only research deemed likely to produce specifiable short-term results. This, he believes, discourages investigators from pursuing long-term or high-risk research. A colleague, corroborating this view, states that he is able to develop essential instruments only by resorting to subterfuge.

Because of the increase in instrument costs, many investigators attempt to pool funds from their separate grants to purchase mutually needed instruments. However, rigid funding procedures often militate against such attempts at effective sharing.

Inflexibility in federal programs requiring matching funds for costly instrumentation also creates problems for universities. Success in meeting matching requirements varies widely. For example, certain chemistry departments have their own endowments and can usually meet matching requirements. On the other hand, some state universities receive little or no state funding for research equipment or related costs; for such institutions, matching requirements are a major financial problem.

Large matching requirements can generate long delays in acquiring needed instrumentation, even among institutions with substantial local funds. An eastern private university was required to provide $150,000 of the total cost of $300,000 for a high-field NMR spectrometer. Difficulty in raising the funds impeded the department's research efforts for more than a year. In effect, such delays deprive the nation of the research for which federal funds already have been obligated.

Variations in Problems

Across Disciplines

Each discipline has its own unique instrumentation problems. In physics, maintaining adequate support shops is difficult. The cost of service contracts is a major financial burden to many biology departments. Instrumentation in high energy physics, surface chemistry, and microcircuitry has become extremely costly. Some schools have begun closing off certain areas of research because they have become prohibitively expensive.

Because much of their equipment must be specially designed and fabricated, physicists are heavily dependent on support facilities and staff. We received several reports of graduate students being used as technicians far beyond levels justified educationally to compensate for insufficient technical support.

Chemistry has evolved from a benchtop science into a predominantly equipment-intensive discipline. In natural products chemistry, even one of the best-funded institutions visited has outmoded instruments. An industrial research administrator notes that inadequate support for the electrical engineering field of microcircuitry is fast becoming a "national disgrace" because of the inability of most departments to acquire the instruments required for advanced training.

In the earth sciences, equipment needs vary according to the subdiscipline. While laboratory experiments such as those simulating the pressure and temperature of the earth's crust are important, field data are essential. Because the earth itself is the laboratory, acquiring data is difficult and costly. Ships, satellites, and computers are essential to some programs. Large-scale, cooperative efforts such as those mobilized in seismic studies of volcanoes and earthquakes are often required. Geochemistry has been revolutionized through the use of the electron microprobe, the mass spectrometer, and the scanning electron microscope. With the advent of the ion microprobe, geochemistry research has become dependent on the extremely expensive analytical tools of modern chemistry.

Biology departments work primarily with commercial equipment and therefore rely heavily on service contracts. These costs have increased substantially during the past few years and have become a major financial burden for many departments. In an eastern molecular biology laboratory, the average cost of service contracts for centrifuges increased approximately 100 percent between 1975 and 1979 (from $379 to $752 annually per instrument). Despite the growing importance of large-scale instruments to biology, state-of-the-art electron microscope facilities in the major research universities have deteriorated.

Severity of the Problem

Most of the university laboratories visited fare poorly in comparison to the nonuniversity laboratories. For example, the government laboratories have more (if not always better) instruments and more extensive support facilities; and they rarely experience serious backlogs of research support projects. Several laboratories have extensive programs of instrument development. While these vary in quality, instrument development in university laboratories, in contrast, is being squeezed out of many research programs.

There is a surprising degree of variation in the quantity and quality of instruments in the commercial laboratories visited, but the best surpass almost all university laboratories visited. Figure 1 compares the age distribution of the current inventories of university and industry instrumentation purchased from 1960 to 1978. The inventories do not include instruments that are unusable due to age or disrepair. The curve for universities represents data from ten institutions, pooled across the five disciplines for which data were gathered (2). The curve for industry represents data from the research laboratories of two major profit-making companies.

The figure reveals a striking disparity in the age of university and industry instrumentation; the median age of the university instrumentation is twice that of the instrumentation in the two industrial laboratories. The philosophy of both industrial organizations is to fund instrumentation at a level such that ideas, rather than instruments, are the rate-limiting factors in research. As profit-making organizations, these companies are nonetheless concerned about the cost-effectiveness of their expenditures, and both have policies encouraging instrument sharing.

The capacity of industrial laboratories to mobilize resources rapidly to exploit suddenly arising opportunities provides one of the greatest disparities between these and university laboratories. Even well-instrumented university laboratories were typically assembled through acquisitions over a number of years. The director of an industrial research laboratory states that it is "pathetic" to see distinguished university researchers struggling to acquire needed instruments by bits and pieces. In contrast, on high-priority projects, industrial researchers can acquire all the instruments they need when they need them.

Scientists in commercial laboratories are not burdened by the administrative paperwork required for the acquisition of research funds and required by related reporting obligations. Indeed, as one university researcher sardonically states, "The ivory towers are now in industry."

However, in some fields, university researchers frequently observe, even the best industrial laboratories in this country do not compare with the foreign laboratories that they have visited or worked in. When asked to identify the best-equipped laboratories in their fields, many scientists mention foreign facilities, particularly Japanese and Western European laboratories.

While investment in R & D by both the federal government and industry has declined in this country, it has been increasing in foreign countries, most notably Japan, West Germany, and the Soviet Union. Research in American universities may remain competitive with research carried out in industrial and foreign laboratories by compensating for the lack of instruments and laboratory facilities with people. The capacity to cope by substituting intellectual ingenuity for instruments, however, will likely be nullified if present trends continue.

Assessing the Situation

The deteriorating quality of university instrumentation is threatening the capacity of even the best institutions to conduct research and provide first-rate training. This deficiency retards the pace of research because the energies of research scientists and graduate students must be redirected from innovative investigation to subsistence activities. Both new and old lines of inquiry are being closed off because of difficulties in obtaining essential but costly instruments.

University scientists often expand the capacities of existing instruments through modifications made in the course of their research. A recent study showed that of 44 improvements that were incorporated into a commercial instrument, 32 were contributed by university scientists (*3*). But lack of access to state-of-the-art instruments and sufficient support facilities may diminish the role that universities play in making such contributions. Also, since over half of the nation's basic research is conducted in universities, the deterioration of university instrumentation may have serious consequences for U.S. science in terms of international competition.

We identified three causes for the severity of instrumentation problems in universities:

1) *Decreased federal support*. Federal support for basic academic science has not kept pace with the rapidly rising costs of conducting research. Strained local budgets in many universities cannot compensate for declining federal funding. Funds for instrumentation have been severely curtailed. For example, the proportion of funds allocated by the National Institutes of Health (NIH) for laboratory equipment declined from 11.7 percent in 1966 to 5.7 percent in 1974 (*4*). Scientists report that they often do not request needed instruments for fear of jeopardizing the basic proposal. To accommodate restricted budgets, the principal investigators, peer review committees, and program officers preserve research manpower and trim instrumentation and support equipment from proposals. This reflects the fundamental importance of scientific and technical staffs to the strength of research programs and the need to maintain the training mission of universities. However, the continued choice of personnel over instruments will lead to further deterioration in the quality of instruments available to conduct research. The academic research system is consuming its capital, and the grace period during which the system can operate effectively on earlier investments is ending.

2) *Inflexibility within the project system*. Current regulations make it very difficult for researchers to pool expenses for acquiring and maintaining instruments to be shared among their projects, especially when the support is provided by different agencies. These regulatory barriers impede the efficient utilization of instrumentation funds that do exist and ignore the research benefits gained when instruments are shared and costs are appropriately pooled (*5*).

3) *Insufficient support for maintenance*. Inadequate provision for maintenance often leaves instruments dysfunctional for extended periods and decreases their effective life. Even when researchers and their students are able to compensate for the lack of maintenance support by performing such necessary tasks themselves, they must do so by diverting valuable time from research and training programs.

Current Government Programs

Federal funding of university instrumentation comes from a number of sources, principal among them the following:

1) *The project grant system*. This system has been very successful in channeling federal funds into high-quality research, but intense competition for the limited funds available has adversely affected instrument acquisition.

2) *Special instrumentation funding programs*. These programs, such as those sponsored by NIH and NSF, have been helpful in supplementing the project system and encouraging the sharing of expensive instruments. However, a number of these programs do not support installation, housing, or operation and maintenance costs and require that the university provide matching funds that are often difficult to acquire from local sources.

3) *Formula grants*. These institutional awards are established on a formula that is related to some segment of the annual federal R & D project funding of the institution involved. The biomedical research support grant (BRSG) of NIH is generally considered to be the most important and successful of the existing formula grants. Funds provided by BRSG's, although limited, have proved effective in supplementing local sources to meet start-up costs and other instrumentation needs. The NSF administered a formula grant program from 1961 to 1974; over half the funds provided were used to acquire instruments (*6*).

4) *Block-funded research centers*. These centers, such as the materials research laboratories funded by NSF, provide stable sources of instruments. Directors and investigators utilizing the centers point out their flexibility, efficiency, and ability to successfully foster instrument sharing. However, their scope is narrow relative to the full range

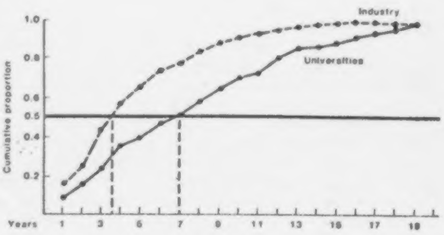

Fig. 1. Mean age of instruments in universities compared with that of instruments in industry (proportion of instrumentation inventory purchased less than *n* years ago). Values for universities are averages of the data for 54 departments and subdepartments of ten institutions, values for industry are averages of the data for two major industrial research laboratories.

of university research, and few institutions have them.

5) *Regional programs*. A number of regional instrumentation programs have been developed. For example, in 1978 NSF devised a program to provide regional access to expensive state-of-the-art analytical instruments. At some level of cost, it is clear that regional or national facilities are necessary—that the instruments required to support the research are simply too expensive to remain under the purview of the individual researcher, a single department, or even an institution. The high energy physics community has faced this problem for years.

However, there are several difficulties in working through regional centers. These include the time and expense of travel, inadequacy of the centers for training, and delays in obtaining experimental results. The facilities are also perceived by many to foster conservative science because the time and expense involved in their use creates a reluctance to undertake high-risk experiments. The centers are young, and some of their problems can be ameliorated; others, however, are inherent to regionalization.

In creating new programs, the choice of providing instruments on an individual, university-shared, or regional basis must be carefully evaluated in terms of the trade-off between such factors as instrument cost, expense of time and travel, and the flexibility and vitality of laboratory-based research.

Recommendations

Identification of the causes for deterioration in the quality of university research instrumentation suggests policies that could rectify the situation. Federal policy for the support of research instrumentation requires new funding mechanisms emphasizing flexibility as well as additional funding. We propose the following funding strategy:

1) *Strengthen instrumentation funding in the project system*. Program managers are generally well aware of instrumentation funding problems but are forced to make unsatisfactory compromises due to limited resources. Increased support through individual research grants and contracts is needed. This would alleviate many of the problems documented here. To accomplish this, the size of individual awards must be increased and a larger percentage of funds allocated to the development, acquisition, and maintenance of instruments. Instrument sharing must be encouraged, and regulatory barriers to the pooling of resources must be eliminated.

However, the project system is not designed to meet the special problems of acquisition of expensive (usually shared) instruments, nor does it effectively address problems such as the funding of departmental support facilities and staff, start-up funds, and matching requirements. The system lacks the flexibility to allow researchers and their institutions to meet unexpected local needs and seize opportunities. While it is, and should remain, the primary mechanism for the support of instrumentation, the project system cannot meet the full range of instrumentation needs by itself even if additional funds are provided.

2) *Expand special programs for funding instrumentation*. Expansion of the special funding programs, with provisions to ease the financial burden on institutions forced to meet stringent matching requirements, is a second important means to increase the level of instrumentation funding. University contributions toward the housing, operation, and maintenance of instruments should be considered part of the matching requirement. This would provide not only a means of upgrading major instruments but also ensure their continued availability.

3) *Encourage increased industrial support for university instrumentation*. Industry is dependent on universitites to train its scientists and engineers. To conduct training at the frontiers of science, universities need state-of-the-art instrumentation. Industry can support university research and training programs by providing essential modern instrumentation or funds for its acquisition. The federal government should develop incentives to encourage such industrial support. While industrial support can play an important role in the acquisition by universities of state-of-the-art instrumentation, it should be noted that such support would be distributed unevenly across disciplines.

4) *Create in NSF an instrumentation renewal program with flexibility to meet diverse institutional needs*. In our judgment, a carefully designed new program, restricted to instrumentation and directly related needs but allowing local allocation decisions, would be the most effective means of providing the flexible funding required to meet the great diversity of needs that exist across departments and institutions. Instrumentation funds would be awarded to institutions in proportion to the total NSF research support they receive. In that way, these funds would follow the research funds awarded by NSF. The program would operate under the guidance of a university committee of faculty members and research administrators who are in the best position to evaluate the unique instrumentation needs of their institution.

This mechanism would provide a local source of flexible funds that could help provide start-up money, support instrument acquisitions for senior investigators seeking to branch into new areas, meet matching requirements, fund the facility renovation often required with the acquisition of new instruments, purchase support equipment, meet operation and maintenance costs, and fund departmental support facilities and staff.

The strongest impression arising from our university visits is the diversity of problems confronting different universities and different departments within the same institution. A source of supplemental, flexible funds would allow researchers and their institutions to respond quickly to unanticipated needs, to capitalize on unique local strengths and opportunities, and yet to remain fully accountable for federal research funds. These funds could be used to address all three causes of the decline in university instrumentation in a manner best suited to the local needs of each institution. No other funding mechanism, in our view, would have a more immediate and direct salutary effect.

References and Notes

1. M. Berger and M. J. Cooper, *Science* 204, 1369 (1979).
2. Data were gathered separately for each field. The age distribution of instruments was similar across disciplines; therefore, the data were pooled for presentation.
3. E. von Hipple, *Res. Policy* 5, 212 (1975).
4. B. Smith and J. Karlesky, *The State of Academic Science* (Change Magazine, New Rochelle, N.Y., 1977), p. 168.
5. The NSF recognizes the inflexibility created by regulations, and, working in cooperation with the Association of American Universities, is conducting an experiment in which researchers are delegated the authority to allocate funds among related research projects, except where such allocations would involve a change in project scope or principal investigator. The experiment has been quite successful and is being expanded to more fields and institutions.
6. J. G. Danek, *Diss. Abstr. Int. A* 37-06, 3533 (1976).

7. We are grateful to Jonathan Amy, John Andelin, James Ebert, Oleg Jardetzky, G. Lorimer Miller, David Robinson, and Richard Werthamer for their dedicated work and sound advice. We greatly appreciate the cooperation we received from numerous administrators, department heads, faculty, managers, and researchers. The study on which this article is based was conducted pursuant to NSF contract [illegible]-PRM-7925829; however, the views expressed in this article do not necessarily represent those of the NSF.

Dr. **Slaughter**. We know, however, that the problem is real and large, even if we can't pin it down precisely. Some estimates indicate that it probably needs several hundred million dollars to begin to come to grips with the problem. You can recognize the magnitude, when you recognize that there are some 30 or 40 high-quality research departments in each of several dozen disciplines that need improved facilities and instrumentation.

To help meet this need, NSF has deliberately stepped up funding for equipment and instrumentation as a proportion of the total research budget. As you know, the $75 million program for research laboratory modernization proposed in our January budget was eliminated in the March budget revisions. This action was taken primarily as a matter of budget stringency; I hope we will be able to pick it up later.

Mr. Chairman, I think I have addressed all of the points that you asked us to discuss with you this morning. I and the National Science Foundation staff who are here would be happy to answer any questions that you or members of the subcommittee may have.

[The prepared statement of Dr. Slaughter follows:]

Statement of

DR. JOHN B. SLAUGHTER
Director, National Science Foundation

before the

Subcommittee on Science, Research and Technology
of the
Committee on Science and Technology
U.S. House of Representatives
March 17, 1981

Mr. Chairman and Members of the Committee:

I appreciate this additional opportunity to appear before you this morning, to discuss a number of important issues facing the National Science Foundation that we have not addressed in previous hearings. In a difficult year, with many important matters before it, this Committee has given generously of its time to the Foundation. This is very deeply appreciated. As it has in the past, the debate which you have stimulated here in the past two weeks has been as valuable to us as it has, we hope, to you.

Before taking up the specific matters with which we are concerned today, I would like to make a few general comments concerning the program of the Foundation and the Administration.

First, Research: The research programs are the heart of the Foundation's efforts, now and in the past. We receive and evaluate over 25,000 research proposals a year, each of which is prepared by researchers striving to present a better idea. We support less than half of these, but the ideas we do support account for the heart of the U.S. program of science and engineering research.

We have tried to protect this research activity as much as possible in the face of the overriding need to reduce Federal spending. Thus our proposed reductions have fallen more heavily on science and engineering education and on other efforts which, however important, do not have this fundamental priority. Research has not escaped the cuts, however. It is well to bear in mind that of the total of $320M in cuts proposed, $100M is to come from education, and $220M from programs we characterize as "research and related." Reductions in industry-university cooperative research, for instance, are cuts in research. So are cuts in research opportunities for minorities and women, and for our experimental programs to improve the geographic distribution of research. And so also do cuts in funds to support instrumentation and facilities affect our ability to do research.

The point is not that these cuts are not necessary. In the current economic environment, I think they are. It is just that we have already reduced our research efforts significantly in meeting the President's target. I urge you not to reduce this effort still further.

Second, Ocean Margin Drilling: The Ocean Margin Drilling program is a scientific program, not a resource exploration program. Its predecessor, the Deep Sea Drilling Project using the drillship *Challenger*, has been one of the most successful scientific efforts ever undertaken. The program we are proposing using the new ship *Explorer* shows every indication of being a worthy successor. Neither I nor the National Science Board would support it if it were not.

The oil companies who have joined with us have done so because they have an interest in the science, not because *Explorer* will go looking for oil. They are not being altruistic, but rather acting in what happens to be the long run interest of both the companies and the Nation. In this they are not different from the chemical industry in its support of the polymer centers at Massachusetts Institute of Technology (MIT) and the University of Massachusetts, or industrial support of materials research. In the absence of industry cost sharing, we would be prepared to recommend this program for support wholly by appropriation, although we realize that it would be unrealistic to expect this under current spending limitations. The scientific results of the Ocean Margin Drilling program will be freely published, and some of them may give the oil companies new insights into how to go about looking for oil. That happened when *Challenger* showed in detail how plate tectonics works, and we are all better off as a result. If it happens again as a result of *Explorer's* work, as I hope it will, the difference will be that this time the oil companies will have put up half the cost.

This country must forge a new alliance between government, industry, and the universities in the cooperative support of research. One of the best ways to do this is to joint participation a large scale, challenging project of high visibility, one in which all sides have a strong incentive and commitment to succeed. Ocean Margin Drilling is such a program. The funds we are proposing in FY 1982 are the minimum necessary to complete the detailed planning for the program in an orderly and efficient way, so that we and the Congress can rationally decide whether to go ahead with ship conversion and operation in FY 1983 and later years. In the recent revisions of FY 1982 budget, we have already reduced the program by $4M, eliminating the procurement of long lead time items for ship conversion. Further cuts would make it impossible to complete the planning process in FY 1982. I urge you not to make them.

Third, our Cross Directorate Programs: We have used this term to indicate a group of programs which are related to research, but don't fit easily into the disciplinary structure that is the basis of our budget and our organization. They include research instrumentation, research facilities improvement, research initiation programs for minorities and women, and other activities. They might equally well be called "cross disciplinary" programs, because they all deal with some aspect of research, but are not focussed on particular scientific disciplines.

These programs have been proposed for elimination, because when hard choices had to be made, we had to give them a lower priority than the research programs themselves. This does not mean that because these programs are out of our budget, they are also out of our minds. Within the limits of the resources we will have, we will try to pursue the objectives of all of these activities, but not as separate programs.

I would not try to argue that we can do all the things we want to do, without the funds originally proposed. But the research programs can, within limits, trade off instrumentation and research, encourage minorities and women, and seek to strengthen research programs in all parts of the Nation. I met yesterday with all the Division Directors and other senior staff of the Foundation, to challenge them to develop new approaches to these problems. While it is too early to say specifically how we will proceed in these areas, I am confident that some progress at least can be made.

Fourth, Basic and Applied Research: In earlier testimony I described the rationale behind our recent reorganization. I will not repeat that, but the essence of it is a belief that basic and applied research form a unified whole, and that each will prosper in close association with the other. In the long run, I believe the distinction between the two will largely disappear.

We recognize that if we are to succeed in this integration of basic and applied research, we must change in significant ways the specific procedures by which we do business. To do this, I have recently made several important changes:

- o I am directing the establishment of a new coding system, so that projects will be identified as basic or applied wherever they are in our system. In the past this was accomplished simply by their assignment to either a basic or applied research division. The coding system will provide us the information we need to monitor the integration process.

- o I am directing that each division develop a plan for expanding the number of applied scientists and research users among their ad hoc peer reviewers.

- o I am directing that membership on our advisory panels include applied scientists and, where appropriate, users of scientific research.

- o Finally, the National Science Board has set up, with my support, a Subcommittee on the Coordination and Management of

Applied Research. It will work with me and the Assistant Directors to monitor our implementation of this change, and to develop whatever additional policies and procedures may seem appropriate.

Taken together, I am confident that these initiatives, and our continued attention, will make our new policy towards basic and applied research work effectively.

I would like to turn now, Mr. Chairman, to the three topics with which you asked specifically that we deal in this hearing -- women and minorities in science, international cooperation in science and technology, and research instrumentation.

Women and Minorities

The National Science Foundation believes that the continuing vitality and productiveness of the Nation's scientific and technological effort depends on full involvement of all talented and interested persons. We support the intent of the Science and Technology Equal Opportunities Act, passed last year as part of our FY 1981 authorization. I believe that NSF has a special responsibility to help develop the research capabilities of persons belonging to presently underrepresented groups.

Even under the constraints of a reduced budget, we will meet some of the terms of the FY 1981 Authorization Act. The amounts spent in 1981 for targeted programs for women and minorities will still be greater than in 1980. For 1982, we plan to examine how women and minority scientists can best be encouraged through our on-going research programs.

Let me review actions I have taken to implement the provisions of the Science and Technology Equal Opportunities Act. After passage of the Act in December, I decided that the Director's Office should take the lead responsibility for review and implementation of the Act's provisions. We assembled a task group of representatives from each directorate to design programs, to plan preparation of reports, and to establish the advisory committee called for by the Act. While some of the programs will not now be implemented, we are following through with other provisions of the law, and the task group that has been working on these issues will continue to meet regularly.

On February 25 we established the Committee on Equal Opportunities in Science and Technology, and filed its charter with this Committee and its counterpart in the Senate. Early in January, we sent a letter requesting nominations for membership on the Committee to professional organizations within the scientific community, and to organizations active in promoting equal opportunity for women and minorities in science and technology. We also asked for recommendations from the National Science Board and from the Foundation staff. As a result of that process, we have received hundreds of nominations, many of them highly qualified. The National Science Board will consider my recommendations for membership of the Committee at their meeting later this week and, as soon as we are able, I intend to appoint members of the Committee. After it is organized, I will ask the Committee to explore the nature of barriers that may inhibit women and minorities in scientific and engineering research. I will also ask their assistance in examining how women and minorities can best be encouraged to send more proposals to the research programs of the Foundation.

We have moved strongly, Mr. Chairman, to follow the intentions of the Congress as expressed in the Science and Technology Equal Opportunities Act. Much needs to be done if the Nation is to benefit from the creativity, insight, and enthusiasm that will be released if the real or perceived barriers are lowered. I pledge my energies and those of the National Science Foundation to this important cause.

International Programs

Our international programs have the general objective of facilitating links between scientists in the United States and in foreign countries, to the advantage of both sides. There are two major program elements: International Cooperative Science and International Scientific Organizations and Resources. There is also a third small program that provides travel support to U.S. scientists, primarily to participate in international scientific meetings.

International Cooperative Science provides support for specific cooperative projects, within a framework of some forty bilateral agreements between the United States and foreign countries. It also includes scholarly exchange programs with China, the Soviet Union, and Eastern European countries. The China program is particularly important, with major opportunities for U.S. scholars in gaining access to China as a subject for study, and important foreign policy considerations as well. We have protected it against reduction in the revised budget.

The Soviet cooperative science program has been greatly reduced, however. It operated at a level of $3.2M in 1980, to the significant benefit of U.S. science. In the present political climate, however, it has been reduced to a level of $400,000. The National Security Council believes it is desirable that this minimum level be maintained.

The second major element has supported U.S. participation in international scientific organizations. The International Council of Scientific Unions (ICSU) and the International Institute of Applied System Analysis (IIASA) are the two main organizations. We propose that this program element be eliminated in FY 1982, although we expect that U.S. participation in ICSU will continue to be supported, as it was some years ago, by drawing support from the research programs. ICSU is actually composed of eighteen international scientific unions, each focussed on a specific discipline. Under the proposed budget, we expect that each disciplinary research program would support its own union.

IIASA presents a more complicated problem. The United States and the Soviet Union are the principal supporters, with some 14 other countries playing lesser roles. It has been a success both scientifically and as a neutral forum for communication between East and West. In the present budget situation, however, we propose to terminate U.S. membership. Under the IIASA charter, the U.S. National Academy of Sciences is required to give a year's notice, effective in December, of intent to resign. Thus, we may be required to continue support for U.S. participation through FY 1982. If this is necessary -- and the determination of what we will do here must await the outcome of consultation with our foreign partners -- the necessary funds will be made available from other programs, primarily the bilateral cooperative projects.

Despite these cuts, we intend to maintain a vital and effective international program. Science has always been an international activity, and we have always gained from programs that allow U.S. scientists to learn from their foreign colleagues. Their cost is small, and their returns are great.

Research Instrumentation

Perhaps the most critical problem facing university science today is the need to replace obsolete and inefficient research instruments.

The work of science entails pressing further and further into the unknown. Advances in most disciplines of science and engineering are dependent on fashioning and using new tools and instruments. One can relate dramatic leaps in understanding directly to the development of new instruments or facilities.

The state of the art of modern research instruments advances at a very rapid rate. Instruments at the leading edge 10 years or even 5 years ago may well be obsolete today. Thus the result of a decade of severely constrained funding for science is that many university laboratories are no longer properly equipped. Far too many American university laboratories, for instance, have not yet had the benefit of the advances in productivity that result from modern electronics -- advances that are taken for granted in other economic sectors.

Foundation program officers have been under pressure for a number of years to reduce the amount of support going to each research group, simply because there is not enough to go around. In such situations, there is a natural tendency on the part of investigators to sacrifice equipment in order to keep the research group going, in the hope that major equipment money will be available "next year." This cannot continue, however, for the problem simply gets worse as time goes on.

It is difficult to quantify the instrumentation problem in very precise terms. We have at this Committee's request started to develop better indicators of the state of scientific instrumentation. I will be glad to submit a note about that topic for the record. I would also like to invite your attention to a recent article in Science on this subject. But while precise quantification may not be feasible, there is a great deal of evidence that the problem is both real, and large. Various estimates of the magnitude of the need have been made, but the minimum amount necessary to catch up is probably several hundred million dollars. This is a large number, but not unreasonable when one considers that there are perhaps thirty or forty high-quality research departments operating in each of several dozen disciplines.

To help meet this need the Foundation has deliberately stepped up funding for equipment and instrumentation as a proportion of the total research budget for the past several years. We have gone as far as we reasonably can without a major increment of funds for this purpose. As you know, a $75 million dollar program for research laboratory modernization, proposed in the January budget, was cut out in the March budget revision.

This action was taken primarily as a matter of budget stringency. It has been deferred without prejudice for future consideration.

Mr. Chairman, that concludes my remarks this morning. I will be happy to respond to questions.

Mr. **Walgren**. Thank you, Dr. Slaughter.

With that, I think we'll go to the other members. Mr. Brown?

Mr. **Brown**. I don't have any questions at this time.

Mr. **Walgren**. Mrs. Heckler.

Mrs. **Heckler**. I do have a question.

Mr. **Walgren**. If you're ready, why don't you go ahead.

Mrs. **Heckler**. Fine. Dr. Slaughter, I wonder what the impact of the cuts on the women and minorities program will be?

Dr. **Slaughter**. Mrs. Heckler, the impact of those cuts could be much more severe if it were not for the fact that we have a genuine commitment to greater participation of women and minorities. The staff of the Foundation has been discussing the impact. It is our intention to do all that we can within the core research budget to identify and eliminate the barriers to full participation by women and minorities. We are establishing the committee called for by the Authorization Act of 1981. I hope that committee will be in place shortly.

Mrs. **Heckler**. I have very little faith in committees, believe me. I know very little that has ever been accomplished. It's commitment that makes the difference.

Dr. **Slaughter**. This committee will have a commitment. It will have the commitment of the National Science Foundation behind it. The individuals are not just individuals who are anxious to be on another committee. These are people who have been working in this field, who have expressed enough interest and desire that so believe we can make a difference.

Mrs. **Heckler**. What is the goal of the committee?

Dr. **Slaughter**. The goal of the committee has two parts. One is to identify and help remove barriers. The other is to get more meaningful participation by women and minorities in the research programs of the National Science Foundation.

Mrs. **Heckler**. Will the Resource Centers for Science and Engineering be eliminated as a result of the President's cuts in the women and minorities program, and what will the effect of that be?

Dr. **Slaughter**. Funds for an additional resource center in our science and engineering education program will not be available. I think the consequences can be serious in terms of our abilities to bring together the universities, the public schools, and the private sector interested in science and engineering education, particularly the improvement of opportunities for minority students is concerned: We're gravely concerned about that.

Mrs. **Heckler**. I think the size of the cuts in the social and the behavioral sciences is very, very troublesome, because of the depths of the cuts. What effect will that have if that level of reduction prevails?

Dr. **Slaughter**. Mrs. Heckler, the proposed reductions mean that the lion's share of the social and economic sciences programs will not be funded. As you know from, earlier testimony, the proposed reductions are in the neighborhood of three-quarters of the original plan. Quality work has been supported in these areas. We know that there are significant sets of social scientists, and people active in the fields of economics and related behavioral sciences, who will not have a place where their proposed research can be supported. That could have a significant impact on our ability to understand many of the important issues facing the country today, including the role of human beings in the process of innovation and productivity and strengthening economy.

Mrs. **Heckler**. Was behavioral sciences among the initial purposes for the foundation of the NSF?

Dr. **Slaughter**. It was never clearly understood. I believe it was 1952 when the debate began. It became an explicit part of the statutory mission of the Foundation some time later.

Mrs. **Heckler**. Do you know in what year?

Dr. **Slaughter**. 1968, I'm advised.

Mrs. **Heckler**. So initially, you were dealing with the so-called "hard" sciences, and then it shifted to behavioral and social sciences?

Dr. **Slaughter**. That's right, they were added explicitly in 1968.

Mrs. **Heckler**. Well, we have a very difficult task on the subcommittee. It seems to me that if we want to make some really substantial reductions in the budget, somehow these incredibly deep cuts in the social and behavioral sciences seem extreme, and therefore it could better serve the overall purposes of the institution if we found other areas in which reductions could be made rather than this one particular discipline, almost a whipping boy. I don't know if you could suggest areas in which cuts could be made or programs can be tightened.

Do you have any recommendations to make to the committee on that basis?

Dr. **Slaughter**. Mrs. Heckler, I made a strong plea that the committee carefully examine NSF's overall research budget, recognizing the importance of supporting the core research program we presented to you. Deep cuts already have been made in other areas of our research programs—over $200 million. I would be gravely concerned if other research programs within the Foundation were reduced. We just don't believe that that would be the best judgment at this time.

Mrs. **Heckler**. So you prefer to have the reductions come in the areas in which they have been targeted thus far?

Dr. **Slaughter**. I think that support for the physical and life sciences is absolutely imperative. I believe the reductions are severe, but I do not believe that core research should be reduced in order to place funds back in other areas. I'd be concerned with that.

Mrs. **Heckler**. I have no more questions.

Mr. **Walgren**. Thank you, Mrs. Heckler.

That's exactly the line that I'd like to pursue just a little bit. The administration recommends increasing the funding in these core areas. From your perspective in viewing the National Science Foundation, would you make those increases at the cost of these cuts, or would you rather have the increases, or would you rather have the cuts? [Laughter.]

Dr. **Slaughter**. I'm not absolutely sure I know quite how to answer that. [Laughter.]

Mr. **Walgren**. I'll rephrase the question. I understand that you support basically the thrust of preserving the core sciences, in view of the economic circumstances that the agency is in. In fact, the administration is proposing increasing some of the efforts in the physical sciences, as I understand it. Would you make those increases at the cost of these cuts?

Dr. **Slaughter**. Mr. Chairman, I think we must look at those increases in the perspective of several years. In fact, Federal support of the physical mathematical, and computer sciences in many cases, has not kept up with inflationary costs. We see the increases for NSF as providing some improvement in the ability to conduct research. But in some cases the increases barely enable the conduct of important experimental research that needs to be accomplished.

So I see the increases in the mathematical and physical sciences in the biological part of our biological and behavioral sciences, and in some cases, the geophysical sciences, as merely funds necessary to carry on a nominal research program. I do not see them as large increases. Consequently, it's difficult to say that we are feasting in those areas, while at the same time, we are experiencing significant declines in research in social and economic sciences.

I believe that we have to protect those core research programs. I regret that science and engineering education and the social and economic sciences have been identified for such major reductions. I do not believe, however, that the appropriate approach is to identify funds from the other research programs as a means of correcting the reductions that have occurred. I just don't see that as a positive approach.

Mr. **Walgren**. Well, you can understand our concern, when the testimony essentially was that these programmatic eliminations were really made from the outside and were not, at least originally, recommended or endorsed in any way by anybody within the science committee or within the National Science Foundation.

Let me ask Dr. Cota-Robles the same question. What we're trying to do is make a judgment of how valid these priorities are that were set by the budget arm of the Executive and without NSF guidance—did they make the right judgments? In particular, is it your judgment that in order to increase funding in the core sciences, that we should be cutting back to the degree which we are in behavioral and economic?

Dr. **Cota-Robles**. Congressman Walgren, first of all, I would like to have you understand that I recognize we must make reductions because the country does need to cope with an economic crisis.

However, I do believe that the cuts have been, as Dr. Slaughter said, too severe.

I would like, also, to comment upon your use of the word "increases." In many cases these are only apparent increases, because they really are just trying to keep up with inflation. Actually they do not even keep up with inflation.

In my own area—the biological sciences—inflation barely has been met. As you have probably heard already, in some of these areas perhaps 25 or 30 percent of the proposals presented are approved for support, so that we have not had any real increases that would permit taking new ideas and new approaches to fund larger numbers of new proposals.

I also believe that one very important component of the National Science Foundation's responsibilities, within the context of supporting research, is supporting the development of potential for research. And one important area of potential is that of women and minorities—groups that have not been included or given an opportunity to contribute their talents.

I want to emphasize that I believe we have a pool of talent that has not been utilized properly by American society. As we come to the future, to the 1990's and so forth, we will begin to realize a greater impact of the lack of development of this potential.

Mr. **WALGREN**. Thank you.

I feel I somewhat interposed myself there.

Mr. Dymally?

Mr. **DYMALLY**. Thank you, Mr. Chairman.

I'm please to see Professor Cota-Robles. As a member of the board of regents of the University of California, I had the opportunity to observe his work and was very impressed with his scholarship and commitment to minorities in science education.

I have a question for Dr. Slaughter.

On the ocean margin drilling project we hear a lot of talk—and there were some critical questions here—about the involvement of the oil companies last year. I suspect they're not the best partners to have in any project, given their large profits. But there is another segment that we don't hear very much about. And that is the involvement of the aerospace industry in this project.

Is it not true that some of the development—some of the instrumentation—will be put together by the aerospace industry?

Dr. **SLAUGHTER**. That's a reasonable assumption, Congressman Dymally.

As the project moves along, we will have what may be referred to as a system integration contract; that's a type of contract familiar to aerospace companies. Technology, large pieces of equipment will be developed. The subset of American industry that can do that kind of work includes companies with experience in aerospace. It's reasonable to assume that they may be competitors for some of the programs. And we would benefit greatly from their experience.

Mr. **DYMALLY**. A second question.

I think Mrs. Heckler asked this question, but I want to be sure that I heard you correctly. Did I understand you to say that the resource centers will be eliminated as a result of these proposed cuts?

Dr. **LANGENBERG**. Perhaps I could respond to that, Mr. Dymally.

Three resource centers have already been funded. We expect to make an award on a fourth this year. Those resource centers are funded up front, so support for the initially agreed upon period for all four of those centers will continue. But if the proposed budget is approved by the Congress, with its severely reduced funding in the science and engineering education directorate, those four resource centers will be the only four resource centers.

Mr. DYMALLY. When you say "four," you're including the proposed fourth?

Dr. LANGENBERG. I'm including the one that we expect to make an award on later this year.

Mr. DYMALLY. I just want to bring to the attention of this subcommittee—and especially Congressman George Brown—that we do not have a resource center on the west coast.

It seems to me, given the tremendous amount of aerospace work and the tremendous amount of scientific research by the University of California, and the fact that California is the No. 1 State in research in aerospace and scientific exploration, it would be appropriate for the NSF to consider an applicant from the west.

Mr. WALGREN. Let me turn to Mr. Skeen.

Mr. SKEEN. Mr. Chairman, I was having a little fun with Mr. Dymally. New Mexico would like to challenge that. We do have one installation.

I have no questions at this time.

Mr. BROWN. Mr. Chairman?

Mr. WALGREN. Mr. Brown.

Mr. BROWN. Mr. Chairman, basically, I want to introduce some new parameters here and see if it will help us to get our priorities a little more in line.

I have the privilege of serving on the Agriculture Committee, and as chairman of the subcommittee that deals with research in that area, and I'm trying to look at the problems of research funding in a cross-departmental way.

I want to have a little discussion with the witnesses if possible with regard to the comparative situation here.

The budget item for research in extensions in the Department of Agriculture turns out to be almost identical to the National Science Foundation's. I think what I have in front of me is the Reagan budget sheets for this function. It lists the following:

Carter budget, 1981, budget authority: $957 million.

Proposed Carter budget 1982, $1,016 million—an increase of 6 percent.

And the outlays follow that closely.

The Reagan budget makes some rescissions in 1981, $7 million, to reduce it to $950 million. But the 1982 proposal is $1,029 million, an increase of 8.3 percent over the 1981 plan. In other words, they have increased the Carter budget submission by about a third, percentagewise. That is, they've increased it from plus 6 to plus 8.

There are some numbers here that I don't understand, but the description says, as follows: The Carter budget proposal was for 4.9 percent real growth in agricultural research—and now the proposed change for 1982 is that real growth in agricultural research will reach 5.2 percent, instead of the 4.9.

Following is the rationale submitted: Agriculture research and extension are a basic underpinning of our tremendously productive agricultural economy. Productivity has increased rapidly in the past, but has slowed in recent years.

Significant constraints, which challenge the agricultural production system, are being cited: Limited water resources, loss of agricultural land, increased production costs because of energy prices.

Then the clincher:

> We must begin to accelerate the improvement of technology now if the United States is to maintain its abundant and diverse domestic food supply at acceptable prices, as well as increasing demand for our world food exports.

Now, what we're confronted with here, is an overall budget submission by this administration which calls for great sacrifice. And we're urged to accept this in toto, on the grounds that one mustn't fool with Mother Nature, or something like that.

And yet, within the research budget of this administration, we have two programs, almost identical in size, one for which this administration proposes an increase over the Carter budget, the other essentially a 30-percent decrease from the Carter budget.

I have my own views as to why this is the situation. But I would like to inquire of the witnesses if they would like to speculate as to why this differential treatment of almost identically funded research budgets?

Dr. SLAUGHTER. Mr. Brown, I might make a couple of comments and ask Dr. Cota-Robles, from his background in biology, to also respond.

Part of the issue here is the lack of careful delineation of responsibilities the Department of Agriculture, the National Science Foundation and, to some extent, the National Institutes of Health. For example, NSF supports a significant amount of basic biological research in the plant sciences and in environmental biology. The Department of Agriculture over the past several years has not increased its support in these areas; the NSF has had to take on more of the support.

NSF supports approximately 80 percent of the universities basic research in environmental biology, for example, excluding oceanography. What we're seeing here is a mixture of responsibilities that has not been carefully sorted; it's a matter of some concern. NSF's Assistant Director for Biological and Behavioral Sciences interacts with her counterpart at the Department of Agriculture in trying to identify these responsibilities.

Dr. COTA-ROBLES. Congressman Brown, I certainly support the need to clarify the relationship between the Department of Agriculture's role in research and that of National Science Foundation. But speaking specifically to your query, it seems to me that your answer—must be framed in the experience we have had in the last few years, in which you have had members of the National Science Board and the National Science Foundation try to speak to the support for basic research, long-term research.

I think in Agriculture the research frequently has been fairly short term, and it is easy to see some of the immediate returns from such research. However, the National Science Foundation, in the support for basic research, finds the returns are more difficult to understand and predict. Therefore, these returns probably are not readily recognized by people who are concerned with trying to manage the budget over the immediate short range.

Dr. LANGENBERG. Mr. Chairman, if I might respond further to Congressman Brown. While it is true that the overall budget at the Foundation, as amended, is reduced considerably below the January proposal, those reductions are strongly targeted in particular parts of the Foundation's programs; other parts are left relatively unscathed.

In the biological sciences, there are some reductions below the original January proposal, but those reductions leave the amended budget proposal with increases in research funding at or about the projected level of inflation.

Mr. BROWN. Well, I appreciate the response that you've made. Yet the question really is: How do we set relative priorities between comparable programs in different organizational settings?

And you raise the point that the cuts in NSF in the proposed Carter budget have been selective, the selection we all know, social sciences and so on. Yet, within the agricultural research budget, there is research on agricultural economics, there's research on agricultural sociology, there's research on a number of other social sciences, psychology of pigs and a number of things like that. [Laughter.]

Mr. BROWN. And in addition to that, there is a very large extension budget, which is what we would call scientific education. And it's not cut.

As a matter of fact, it's set for an increase. And I'm wondering how these relative priorities are set, because we're asking in this committee to accept certain priorities. And in the Agriculture Committee, we're asked to accept the increases as an example of immutable priorities which can't be changed. And yet, somewhere within this great system of ours there must be some way of evaluating the factors that lead to these relative priority settings in terms of what the national interest is, rather than whether somebody doesn't like social science as it's done in one particular place or some such other aspect of the budget.

Dr. SLAUGHTER. Mr. Chairman, we don't know the answer to that question. We did not participate in that determination.

Mr. BROWN. You did not have an opportunity to review the research budgets across the board then?

Dr. SLAUGHTER. That's correct.

Mr. BROWN. You don't know anyone else who made such reviews, such as the science adviser who advises the President on this?

Dr. SLAUGHTER. In the absence of a science adviser at the moment, I'm unaware of anyone who advised the President.

Mr. BROWN. Thank you, Mr. Chairman.

Mr. WALGREN. Let me just be very brief.

No. 1, how much was spent on bilateral international programs this last year?

Dr. SLAUGHTER. We can provide that information for the record.

[The information follows:]

Question. Number one, how much was spent on bilateral international programs this last year?

Answer. The obligations for "International Cooperative Science" were $9,158,851 in fiscal year 1980.

Of this amount, $467,412 was for U.S.-China Cooperation in Basic Sciences and $1,185,595 was for U.S.-U.S.S.R. Cooperative Research.

The remainder, $7,505,844, was for cooperation with nearly 40 countries, grouped below, for convenience, in three categories:

"Industrial" countries, principally Australia, France, Italy, Japan, New Zealand.

"Socialist" countries, mainly Bulgaria, Hungary, Romania; plus support of the National Academy of Science's exchange program with academies of the U.S.S.R. and Eastern Europe.

"Developing" countries, principally Argentina, Brazil, Korea, Mexico, Venezuela, plus several other countries in Latin America and Southeast Asia.

Mr. WALGREN. Second, it's clear, is it not, that if NSF doesn't do it, nobody will? There is no backstop of that program.

Dr. SLAUGHTER. Correct.

Mr. WALGREN. And third, your testimony, Dr. Slaughter, is that if we do not do something specifically for instrumentation, that there will be no further effort able to be made by NSF with respect to instrumentation? To wit, your statement is that in the past, as I understand, the Foundation has deliberately stepped up funding for equipment and instrumentation as a portion of the total research budget for the past several years. We've gone as far as we reasonably can without a major commitment of funds for this purpose.

Dr. SLAUGHTER. Yes, sir. I'm saying we will do all we can within the constraints of the present budget. But that a shot in the arm is required.

Mr. WALGREN. You're also saying that you've done all you can in the past several years.

Dr. SLAUGHTER. That's correct. All we can do is continue the same.

Mr. WALGREN. Thank you very much.

I have nothing further.

I appreciate very much the panel coming. You've been more than understanding of the committee in your presentations and the time you've spent with us.

So, thank you very much, Dr. Slaughter, and, in particular, Dr. Langenberg and Dr. Cota-Robles. We appreciate it.

The next witness is Dr. James Fletcher.

We're happy to have you, Dr. Fletcher.

Dr. Fletcher was the former Administrator of the National Aeronautics and Space Administration, and holds a chair of energy and technology resources, and is a director of the energy resource program at the University of Pittsburgh.

He's here, really, because, in addition to his background, he recently headed the National Science Foundation team for President Reagan.

That's why the committee was particularly interesting in talking to you, Dr. Fletcher, even though you do come from Pittsburgh, Pa.

[A biographical sketch of Dr. Fletcher follows:]

DR. JAMES CHIPMAN FLETCHER

Dr. James Chipman Fletcher, former Administrator of the National Aeronautics and Space Administration, currently holds the William K. Whiteford Chair of Energy and Technology Resources at the University of Pittsburgh, where he is also Director of the Energy Resources Program. Dr. Fletcher has had an outstanding career in the fields of industry, education and government, notably through his prior association with the Hughes Aircraft Company, the Ramo-Wooldridge Corporation's Space Technology Laboratories, and the Space Electronics Corporation (1948-1964); as eighth President of the University of Utah (1964-1971); and, as NASA

Administrator during the years, 1971 to mid-1977, when he returned to the private sector. Dr. Fletcher has served on the President's Science Advisory Committee, as well as other Presidential Task Forces.

Dr. Fletcher is presently a Member of the Technology Assessment Advisory Council, Office of Technology Assessment, U.S. Congress. He is a Fellow of the American Academy of Arts and Sciences, the American Astronautical Society, and the Institute for Electrical Engineering, and an Honorary Fellow of the American Institute of Aeronautics and Astronautics. He is a Member of the National Academy of Engineering, serves on its Council, and is NAE representative to the Governing Board of the National Research Council. Dr. Fletcher holds a number of honorary doctorates and awards, including the U.S. Air Force Exceptional Civilian Service Medal and the NASA Distinguished Service Medal.

STATEMENT OF DR. JAMES C. FLETCHER, PROFESSOR, UNIVERSITY OF PITTSBURGH, AND FORMER HEAD, NATIONAL SCIENCE FOUNDATION TRANSITION ADVISORY TEAM FOR PRESIDENT REAGAN

Dr. **Fletcher.** Mr. Chairman and members of the committee, I was hoping to comment on the fact that I'm very disappointed to see that former Chairman Brown decided to leave the committee. But I'm very happy to see that my congressman from Pittsburgh is the new chairman.

It is always a privilege to come before this committee, particularly at this time, to give my own views on the status of the National Science Foundation's efforts to fulfill its statutory mandate.

I have been involved with the NSF since its inception, in one capacity or another, particularly while I was at the University of Utah, as president; and as a member of the President's Science Advisory Committee under President Johnson and, later, President Nixon. And more recently, as you've mentioned, I was the team captain of transition planning for the new Reagan administration.

During this transition period, we had an opportunity to be brought up to date on the various programs at NSF, and I cannot, obviously, comment on all of them. But I'd be glad to give you my views on any that you wish to hear about. Particularly, there are some that I want to point out.

Let me start by saying that the National Science Foundation has really done well in fulfilling its commitments to provide for a healthy science program in this country, and to monitor annually the status of the health of this program. As a result of their efforts and, of course, those of the National Science Board, science in the United States is unequaled anywhere in the world, as measured by almost any reasonable yardstick.

Particularly, however, one could merely look at the Nobel prizes in the natural sciences that have been given to Americans since the inception of NSF.

Although no program is perfect, science in the United States has certainly flourished, and a great deal of that achievement is due to the efforts of the National Science Foundation.

However, the same cannot be said of the status of technology, and I've testified on the difference between science and technology before this committee before. But I'd like to reemphasize that difference. Technology is often translated into engineering, although it doesn't mean the same thing.

In comparison with countries like Japan and West Germany, technology seems to be losing ground rapidly, and with a correspondingly devastating effect on the Nation's overall productivity.

In my opinion, we have not fallen behind the Soviet Union in military technology; but that, of course, is not the Foundation's responsibility, but rather that of the Department of Defense.

One could ask the question whether technology, particularly industrial technology, in the United States is the responsibility of any Government agency. I know Congressman Brown had hearings on that, last year. But, to be specific, it certainly does not seem to have been the chief responsibility of the National Science Foundation. Attempts by the Foundation to deal with portions of this problem have not met with the same success as that of the science program, especially in the natural sciences, such as physics, chemistry, geology, biology, and so forth.

Many problems that the National Science Foundation now must deal with may very well be related to the same problems the Nation is facing; but may not, in fact, be the responsibility of the Foundation. Our country, as well as the other developed nations of the world, is in the midst of a new era or new age. We at NASA like to call it the "space age"; but other people have given it other names: some, the "scientific revolution," and Zbigniew Brezinski calls it the "technetronics revolution." That's a little hard to say, and I prefer the "space age."

But nevertheless, it's quite different from the Industrial Revolution, from which we all recently emerged, in the sense that high technology based on very sophisticated science is the major component.

Such technologies as microelectronics, aerospace, biomedical instrumentation, computers, photocopying, and much of our military devices are all part of this revolution. All these have had profound effects on our society—some of them bad, no doubt—but the main effects are that the various institutions which make up our society have not been able to keep pace with this rapidly accelerating change.

Often, new Federal or industrial programs simply do not recognize these changes and, inadvertently, compromise our ability to accommodate them. One major aspect of this in the industrial sector is the rapid movement of Japan and Europe into markets formerly dominated by the United States: consumer electronics, automobiles, steel, and, more recently, commercial aircraft and even computers.

I imagine Dr. Bromley will have more to say about this, in his testimony.

Although these national problems must receive the highest priority from both the new administration and the new Congress, the issue is much bigger than NSF can possibly address. However, it is well to note, during any hearings on NSF's budget, which programs can aid in the solution to this urgent problem. And I will try to do so, as I move along.

In summary, then, one could say the following about NSF's overall program:

First, the natural sciences. As we've already discussed earlier, the support for natural sciences has been excellent, and there's no deviation from continuing support for these.

Second, social and behavioral sciences. Several years ago, there were questions about research in the social and behavioral sciences, questions coming primarily from the Congress.

Although this program has never been large, there apparently were a number of difficulties early in the program, related to the fact that it is hard for the lay public to differentiate between "social science," as it's termed, and other seemingly related fields, such as philosophy, ethics, value systems, and things of that sort, in which many have criticized the Foundation for improperly involving itself.

In my opinion, most of these criticisms have been addressed by the Foundation, and have been corrected, so that the remaining social and behavioral science programs are sound and should be supported.

In the most recent budget, I noticed these were severely cut, and I can only guess that the reasons for this cut tie back to several years ago, when there were indeed some serious questions about NSF's proper role in these sciences.

In my opinion, however, most of these earlier criticisms have been accommodated in NSF's current program—and, by "current," I mean fiscal year 1981. A funding level of the magnitude proposed in fiscal year 1981 is about the right size.

Third, science education programs. It's never been entirely clear what role the National Science Foundation should be taking with regard to science education in the primary and secondary schools. On the college and graduate programs, it's much clearer. But, in the primary and secondary schools, there always is a question.

It is clear that NSF has the responsibility of improving the overall health of science and technology in the Nation, and that this health does depend on what happens in the primary and secondary schools.

It's also clear that we, as a nation, are not properly addressing science education.

Two facts, for example, are quite evident: We are not producing, anywhere near enough technically trained people, especially engineers, for use by either government or industry, particularly in certain categories of the engineering profession, such as electrical engineering, chemical engineering, mining engineering, and several others. The second point is that the general public does not have sufficient familiarity with science and technology to be able to judge their value.

I'm not referring to this committee, because you've had enough hearings to be able to be what we call "scientifically literate." But the general public is not.

With respect to the second question, some interesting experiments using college sophomores were made by Drs. Barry Singer and Victor Benassi, at Long Beach State College. They state—I'm quoting:

> We have tested hundreds of college sophomores over the past several years, with the problem of estimating the duration of flight of a 4-pound and a 2-pound lead weight dropped simultaneously from the same 16-foot height.

I guess that's about the height of the ceiling—

> Over half the students gave different estimates for the flight durations of the two weights. Fifteen percent gave estimates in the range of 4-50 seconds, perhaps envisioning them floating down like paper airplanes.

By the way, I'd be glad to demonstrate this, if you wish. [Laughter.]

Dr. FLETCHER. I think most of you are aware that it's approximately 1 second.

> On the same test we found that over half the students did not know that water in a tipped glass remains level, and many believed that islands float in the ocean and that the moon remains fixed in the sky over them, but is only visible at night.

This is the end of the quotation.

This may not seem surprising to many in this audience, but to a scientist it is a horror story, worse than discovering that many high school students can't read.

Clearly, in this new scientific age of which we are part, we need scientific literacy on the part of all society.

High quality science teaching is also a necessary requirement for preparing for careers in both science and engineering. Science and engineering both depend on science training in primary and secondary schools.

In Europe and Japan, decisions are made by students still in the primary schools—that is, before the eighth grade—on the career path each is to take; and two- and sometimes three-track systems are followed for the higher grades. I don't believe the United States is ready to accept this multiple-track system, since it tends to have the undesirable effect of freezing a student's career long before he is mature enough to make such a permanent choice for his later life.

I do strongly believe, however, that more options for science-oriented students need to be made available earlier in their careers.

Now, one might ask why science education in primary and secondary schools isn't more properly the role of the Department of Education, instead of NSF.

I think it relates to the problem of the serious lack in this country of personnel trained in the very specialized area of science and to the general lack of public understanding, rather than to the overall primary and secondary school education enterprise, which is clearly the responsibility of the individual State and local governments, partially supported, of course, by the Federal Government. And, to some extent, this has been supported by NSF.

In this instance, scientists are better qualified to support this program than are professional educators, since most professional educators themselves, unfortunately, are scientific illiterates.

At any rate, so long as NSF's program deals with the question of better training for science teachers in the primary and secondary schools, this is an appropriate role for the Foundation.

It is probably not a wise thing for the Foundation to experiment haphazardly with students in their early years, as sometimes was thought to have been sponsored by the Foundation—and, in fact, probably was. Nor should it try to indoctrinate students. But, rather, should provide to them the opportunity of learning about science and technology in the same way they learn about reading or writing.

Fourth, support for the engineering schools. The engineering schools have a serious problem, both as to faculty and equipment for educational purposes. We discussed that in your earlier remarks.

In most engineering schools, there is a shortage of trained faculty because, on the whole, faculty salaries have failed to keep pace with industrial salaries, particularly in the engineering profession. As a result, engineering schools have survived partly by acquiring inadequately trained people; and partly by the use of foreign-born faculty who, quite often, are not eligible for employment in the industrial sector.

I don't know how the National Science Foundation can remedy this situation, except to, on the whole, increase general engineering support sufficient to attract superior faculty willing to work for low pay, because of the excitement involved in doing research.

The problem of recruiting and retaining faculty, of course, must remain in the universities involved.

As far as engineering school resources are concerned, there is a shortage of new equipment—we call this new equipment "instrumentation," but it's the same thing—to meet the needs of the rapidly advancing technology in certain engineering disciplines. There is also the need to replace old equipment which is either worn out or has become obsolete.

The support for engineering equipment in American universities ought to be substantially increased, and NSF is the proper agency to provide it.

As far as the overall responsibility for the health of U.S. technology is concerned, it is not clear what more belongs with the National Science Foundation.

In fact, it is not clear what role, if any, the Government should play in improving the health of technology, in the same way that it's not clear what the Federal Government should be doing to improve the health of the economy.

By the way, I think the two are related. We sometimes forget this relationship.

This surely must be the subject for another series of congressional hearings, and I'd be glad to comment on that subject at some later time.

For the present, it should be sufficient to say that I, and most of my colleagues, do not believe that the National Science Foundation is the proper place or institution in which this responsibility for technology should be vested.

Now, as far as the recent budget revisions proposed by President Reagan, I must say at the outset that I have not studied this in detail. They were just disembargoed last Tuesday, as I recall, and I can only comment on the broad program.

But, based on a quick overview, I think I could make the following comments, and support them:

First, the natural sciences seem to be adequately supported with the high priority they should have. The difficulty, of course, in having the highest priority, is that the lower priority programs tend to be overly cut, or sometimes eliminated together.

The program in the social and behavioral sciences seems to be unreasonably curtailed. Now, we lump them all together—in biological, social, and behavioral—and I notice, from my point of view, biological was not cut to the same degree that the social and behavioral sciences were. So, I only have addressed the social and behavioral sciences.

In my opinion, most of these difficulties have been corrected that were seemingly involved earlier in the program and the social and behavioral sciences ought to be funded at a level comparable to last year to provide proper continuity of funding for researchers in this field.

It would be my hope that this budget could be augmented, either in the fiscal year 1982 budget, or at least in the following year's budget.

The science education program clearly needs restructuring within the Foundation, but not to the point where it should be cut to zero.

In the past, there have been many good programs for training science teachers and keeping them current with recent advances. One particularly comes to my mind as having been extremely useful during my tenure as president of the University of Utah, and that was the Summer Institute for Teachers.

Programs of this sort should not only be reinstated, but also increasingly supported, so that primary and secondary schools begin to play their proper role in restoring the health of our Nation's overall technology enterprise.

Even though NSF's role is unclear in this overall technology revitalization program, if you like, certainly in the primary and secondary schools, it should play a major role.

Now, in other programs, apparently severe cuts were made in the programs labelled "cross-directorate" and "scientific technical and international affairs"—STIA.

I have no doubt that some of the programs would have served a useful purpose. But, in a year when serious attempts are made to cut overall Federal expenditures, I would not quarrel with the decision to cut or eliminate most of these programs.

However, similar cuts were made in the program labeled "research facilities, equipment and instrumentation."

It's a little hard to dig this out, because it's spread out throughout the major science and engineering line items.

However, there is no doubt that most of these items are critical to the health of science, and particularly engineering, and would surely need to be examined closely by Congress, to determine how much should be restored.

I'm afraid the OMB criterion of "no new starts" is carried to an unreasonable extreme, when applied to new facilities and, especially, new equipment and new instrumentation.

In conclusion, then, it appears that the National Science Foundation is a mature and healthy organization. It does an outstanding job in the natural sciences, but not as good as it could do in some of the newer thrusts, such as engineering research, and in the social and behavioral sciences.

By and large, the mandatory programs—such as the international programs, the Antarctic program, and the atmospheric research program at Boulder—are quite adequately done. I would hope the Congress would support them, in all of these major programs.

One thing ought to be mentioned in passing. And that is that science—and, to some degree, the same can be said for technology—is not a program you can strengthen or weaken on a year-to-year basis; but one that must be redirected gradually, lest the whole enterprise become deathly sick from shock treatment.

My experience at NASA has shown that, time and time again, when this kind of shock treatment is applied, a huge amount of taxpayers' dollars are wasted.

One must not expect too much too soon, in the newer thrust of this Foundation.

This, Mr. Chairman, is the end of my statement. I'd be happy to answer any questions, even though I'm not really a panel. I'm just a person.

[The prepared statement of Dr. Fletcher follows:]

STATEMENT BY JAMES C. FLETCHER
BEFORE THE
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
OF THE
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
MARCH 17, 1981

Mr. Chairman and members of the Committee, it is indeed a privilege to be able to discuss with you this morning my views of the status of the National Science Foundation's efforts to fulfill its statutory mandate. As some of you know, I have been involved peripherally with the National Science Foundation since its inception in 1950, and since that time, in one capacity or another, but especially as President of the University of Utah from 1964-1971 and as a member of the President's Science Advisory Committee from 1967 to 1971. Most recently, it fell to me to be the team captain of transition planning for the Reagan Administration. During this period the members of the transition team and I had an opportunity to review the entire program of the Foundation and to be brought up to date on what some of the problems are and the progress that has been made up to the present time. As you know, I'm not at liberty to discuss the content of the Transition Team's report, but I'm delighted to be able to give you my own views of the National Science Foundation's programs.

Let me begin by saying that the National Science Foundation has indeed fulfilled its commitment to provide for a healthy science program in this country and to monitor annually the status of the health of this program. As a result of their efforts and those of the National Science Board, science in the United States is unequalled anywhere in the world as measured by almost any reasonable yardstick. Particularly, however, one can merely look at the Nobel prizes in the Natural Sciences that have been given to Americans since the inception of NSF. Although no program is perfect, certainly science in the United States has flourished and a great deal of that achievement is due to the efforts of the National Science Foundation. However, the same cannot be said of the status of Technology (which often translates into "engineering") in the United States. In comparison with countries like Japan and West Germany, Technology seems to be losing ground rapidly and with a correspondingly devastating effect on the Nation's overall productivity. In my opinion, we have not fallen behind the Soviet Union in military technology but that, of course, is not the Foundation's responsibility but rather that of the Department of Defense. One could ask the question whether Technology, particularly Industrial Technology, in the United States is the responsibility of any government agency but, to be specific, it does not seem to have been the chief responsibility of the National Science Foundation. Attempts by the Foundation to deal with portions of this problem have not met with the same success as that of the Science Program, especially in the Natural Sciences, that is, Physics, Chemistry, Geology, Biology, etc.

Many problems that the National Science Foundation now must deal with may very well be related to the same problems the Nation is facing but may not, in fact, be the responsibility of the Foundation. Our country, as well as the other developed nations of the world, is in the midst of a new era or new age. Some refer to it as the "Space Age," some, the "Scientific Revolution," and Dr. Zbigniew Brezinski calls it the "Technetronics Revolution." It is quite different from the Industrial Revolution, from which we all recently emerged, in the sense that high technology based on very sophisticated science is the major component. Such technologies as microelectronics, aerospace, bio-medical instrumentation, computers, photocopying, and much of our military devices are all part of this revolution. All these have had profound effects on our society (some of them bad, undoubtedly) but the main effects are that the various institutions which make up our society have not been able to keep pace with this rapidly accelerating change. Often new Federal or Industrial programs simply do not recognize these changes and inadvertently compromise our ability to accommodate them. One major aspect of this in the Industrial sector is the rapid movement of Japan and Europe into markets formerly dominated by the United States (consumer electronics, automobiles, steel, and more recently, commercial aircraft and even computers).

Although these national problems must receive the highest priority for both the new Administration and the new Congress, the issue is much bigger than NSF can possibly address. However, it is well to note during any hearings on NSF's budget which programs can aid in the solution to this urgent problem. I will try to do so as I move along.

In summary then, one could say the following about NSF's overall program:

(1) Natural Sciences

Its support for the Natural Sciences is excellent and its procedure for dealing with funding of research in the Natural Sciences need not be changed in any way. In particular, the peer-review system - often criticized in the past - is clearly, at this date, a system which works well.

(2) Social and Behavioral Sciences

Several years ago there were questions about research in the Social and Behavioral Sciences. Although this program has never been large, there apparently were a number of difficulties early in the program related to the fact that it is hard for the lay public to differentiate between "social science" and other seemingly-related fields, such as philosophy, ethics, value systems, and so forth, in which many have criticized the Foundation for improperly involving itself. In my opinion, most of these criticisms have been addressed by the Foundation and have been corrected so that the remaining Social and Behavioral Science Programs are sound and should be supported. In the most recent budget I noticed these were severely cut and I can only guess the reasons for this cut ties back several years ago when there were indeed some serious questions about NSF's proper role in these sciences. In my opinion, however, most of these earlier criticisms have been accommodated in NSF's current program. A funding level of the magnitude proposed in FY 81 is about the right size.

(3) Science Education Programs

It has never been entirely clear what role the National Science Foundation should be taking with regard to Science Education in the primary and secondary schools. It is clear that NSF has the responsibility of improving the overall health of Science and Technology in the Nation and that this health does depend on what happens in the primary and secondary schools. It is also clear that we, as a nation, are not properly addressing Science Education. Two facts are quite evident: (1) we are not producing anywhere nearly enough technically-trained people, especially engineers, for use by either government or industry, particularly in certain categories of the engineering profession, such as electrical engineering, chemical engineering, mining engineering, and so forth; and, (2) the general public does not have sufficient familiarity with Science and Technology to be able to judge their value.

With respect to the second question, some interesting experiments using college sophomores were done by Drs. Barry Singer and Victor Benassi: (1) At Long Beach State College - They state:

> "We have tested hundreds of college sophomores over the past several years (Singer, in press) with the problem of estimating the duration of flight of a 4-lb and a 2-lb lead weight dropped simultaneously from the same 16-ft. height. Over half the students gave different estimates for the flight durations of the two weights. Fifteen per cent gave estimates in the range of 4-50 seconds, perhaps envisioning them floating down like paper airplanes. On the same test we found that over half the students did not know that water in a tipped glass remains level, and many believed that islands float in the ocean and that the moon remains fixed in the sky over them, but is only visible at night."*

This may not seem surprising to many in this audience but to a scientist it is a "horror" story --- worse than discovering that many high school students can't read. Clearly, in the new scientific age,

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*American Scientist
January-February 1981

of which we are a part, we need "scientific literacy" on the part of all of society.

High-quality science teaching is also a necessary requirement for preparing for careers in both science and engineering since both disciplines receive pretty much the same course work throughout the first twelve grades. In Europe and Japan decisions are made by students still in primary schools (i.e., before the eighth grade) on the career path each is to take and two (or even three) track systems are followed for higher grades. I don't believe the United States is quite ready to accept this multiple-track system since it tends to have the undesirable effect of freezing a student's career long before he is mature enough to make such a permanent choice for his later life. I do strongly believe, however, that more options for science-oriented students need to be made available earlier in their careers.

One might ask why Science Education in primary and secondary schools isn't more properly the role of the Department of Education instead of the National Science Foundation. I think it relates to the problem of the serious lack in this country of personnel trained in the very specialized area of science and the general lack of public understanding rather than to the overall primary/secondary school education enterprise which is clearly the responsibility of the individual state and local governments, partially supported, of course, by the Federal Government. In this instance, scientists are better qualified to support this program than are "professional educators" since most professional educators themselves are scientific illiterates. At any rate, so long as NSF's program deals with the question of better training for science teachers in the primary and secondary schools, this is an appropriate role for the Foundation. It is probably not a wise thing for the Foundation to experiment haphazardly with students in their early years, as sometimes was thought to have been sponsored by the Foundation. Nor should it try to "indoctrinate" students but rather should provide to them the opportunity of learning about Science and Technology in the same way they learn about reading or writing.

(4) Support for Engineering Schools

Engineering schools have a serious problem, both as to faculty and equipment for educational purposes. In most engineering schools there is a shortage of trained faculty because, on the whole, faculty salaries have failed to keep pace with industrial salaries, particularly in the engineering profession. As a result, engineering schools have survived, partly by acquiring inadequately-trained people and partly by the use of foreign-born faculty. I don't know how the National Science Foundation can remedy this situation except to, on the whole, increase general engineering research support sufficient to attract superior faculty willing to work for low pay because of the excitement involved in doing research. The problem of recruiting and retaining faculty must remain in the universities involved. As far as Engineering School resources are concerned, there is a shortage of new equipment to meet the needs of the rapidly-advancing technology in certain engineering disciplines, and there is also the need to replace old equipment which is either worn out or has become obsolete. The support for engineering equipment in American universities ought to be substantially increased and NSF is the proper agency to provide it.

As far as the overall responsibility for the health of U.S. Technology is concerned, it is not clear what more belongs with the National Science Foundation. In fact, it is not clear what role, if any, the government should play in improving the health of technology in the same way that it's not clear what the Federal Government should be doing to improve the health of the economy. This surely must be the subject for another series of Congressional hearings and I would be glad to comment on that subject at some later time. For the present, it should be sufficient to say that I, and most of my colleagues, do not believe that the National Science Foundation is the proper place or institution in which this responsibility should be vested.

As far as the recent budget revisions proposed by President Reagan, I must say at the outset that I have not studied these in detail and therefore can comment only on the broad program. Based on a quick overview, I can make the following comments:

(1) The Natural Sciences seem to be adequately supported with the high priority they should have. The difficulty in having the highest priority, however, is that lower-priority programs tend to be overly cut or sometimes eliminated altogether.

(2) The program in the Social and Behavioral Sciences seems to be unreasonably curtailed, probably as a result of the earlier difficulties with this program. In my opinion, most of these difficulties have been corrected and the Social and Behavioral Sciences ought to be funded at a level comparable to last year to provide proper continuity of funding for researchers in this field. It would be my hope that this budget could be augmented, either in the FY 82 budget or at least in the following year's budget.

(3) The Science Education Program clearly needs restructuring within the Foundation but not to the point where it should be cut to zero. In the past there have been many good programs for training science teachers and keeping them current with recent advances. One particularly comes to my mind as being extremely useful during my tenure as President of the University of Utah and that was the Summer Institute for Teachers. Programs of this sort should not only be reinstated but also increasingly supported so that primary and secondary schools play their proper role in restoring the health of our Nation's overall Technology enterprise. Even though NSF's role is unclear in the overall Technology revitalization program, certainly in the primary and secondary schools they *should* play a major role.

(4) *Other Programs* - Apparently severe cuts were made in the programs labelled "Cross-directorate" and "Scientific Technical and International Affairs." I have no doubt that some of the programs

would have served a useful prupose but in a year when serious attempts are made to cut overall Federal expenditures, I would not quarrel with the decision to cut or eliminate most of these programs.

However, similar cuts were made in the program labelled "Research Facilities, Equipment and Instrumentation." This item is spread over all the major science and engineering line items and it is difficult without an in-depth study to decide to what degree such deep cuts could be harmful. However, there is no doubt that most of these items are critical to the health of science and particularly engineering and would surely need to be examined closely by Congress to determine how much should be restored. I'm afraid the OMB criteria of "no new starts" is carried to an unreasonable extreme when applied to new facilities and especially new equipment and new instrumentation.

In conclusion then, it appears that the National Science Foundation is a mature and healthy organization. It does an outstanding job in the Natural Sciences (Physics, Chemistry, Geology, Biology, etc.) but not as good as it could do in some of the newer thrusts such as Engineering Research and Social and Behavioral Sciences. By and large, the mandatory programs, such as the International programs, the Antarctic program, and the Atmospheric Research program in Boulder, Colorado, are quite adequately done. I would hope the Congress would support them in all of these major programs. One thing ought to be mentioned in passing and that is that Science - and to some degree the same can be said for Technology - is not a program you can strengthen or weaken on a year-to-year basis but one that must be redirected gradually lest the whole enterprise become deathly sick from "shock treatment." My experience at NASA has shown that time and time again when this is done, a huge amount of taxpayers" dollars is wasted. One must not expect too much too soon in the newer thrust of the Foundation.

This, Mr. Chairman, concludes my statement and I would be happy to answer any questions.

Mr. WALGREN. Thank you very much, Dr. Fletcher. Even though you're not really a panel you've been breaking some new ground and giving us a framework for making judgments about this that we have not been able to gather from other witnesses. So your statement is very, very helpful.

Mr. Brown?

Mr. BROWN. Dr. Fletcher, I don't want to belabor your statement, which I think is excellent. I just wish that your voice had had more influence on the science proposals in this budget. But I am interested in your comments with regard to the role of the Foundation in technology.

I presume you feel that the initiatives the Foundation has taken with regard to the support for engineering research is an appropriate goal for the Foundation?

Dr. FLETCHER. Yes, indeed, Mr. Brown. I think that is quite appropriate.

Mr. BROWN. The question of whether the Foundation or some other agency should have an overall responsibility for the health of the economy bothers me, as I know it bothers you. Certainly we would all prefer to have the world's preeminent economy operating strictly on a market basis, and with all the free enterprise incentives that exist there and the freedoms that exist. But it appears that we have to look for ways to stimulate this, rather than just hope that it will happen.

And I again point to the agricultural sector, where we have a very close intertwining of Government roles and private enterprise roles; where we have an institutional system of research that works closely with the economic sector; and that the agenda of the institutional research program is set in cooperation with the agricultural community, so that the results of it are, through a fairly complex network, fed out into the private sector.

Nobody, to my mind, has brought out very convincingly the argument that we shouldn't be involved with the agricultural sector of the economy. Now, how does one identify an appropriate way of assisting the private enterprise sector to be the best in the world, and what is an inappropriate way?

Dr. FLETCHER. I'd be glad to dwell on that. As you know, Mr. Brown, agriculture is not the only place where that occurs. Aerospace is another instance. We have a very healthy aerospace industry in this country. That applies to commercial as well as to military aircraft. And we have had, since about—I've forgotten the exact date, but let's say 1950, when NACA was created, a very good relation between the research done by the Government and the aerospace industry.

And to a lesser extent, the same is true of the computer industry, sponsored primarily by NASA and the Department of Defense. There is a good relationship there.

And so I think there are appropriate roles for the Federal Government. I think my remarks were only directed to the National Science Foundation. They have done well in the natural sciences and, by and large, the people that are in the Foundation come from the academic world and not from the industrial world. And so it is not natural for the National Science Foundation to pick up that role.

If they were to do so, it would have to be by an extensive reorganization; not by the small one of moving applied science in with the basic science. I am not sure that is much help in terms of this industrial relationship that you were referring to.

Mr. **Brown**. I raise the question because at least some of the programs which got most severely cut were those aimed at playing some role in this business of restoring health to what, as you yourself say, is becoming an increasingly science-based economy. Obviously this is true in agriculture, and has always been true.

There was one notable difference about the areas you mentioned, aerospace, aviation, and so forth. The original basis for development there was that the Government was the largest and about the sole customer for the product. But that is not true in agriculture.

The Government buys quite a bit of the output of that sector, but by no means all or even a major part. Yet we tend to be somewhat dogmatic in trying to establish rules for the proper role of Government.

Correspondingly, when we translate that down to the proper role of the Science Foundation, it becomes involved in controversy, which is highly unfortunate.

I am really just seeking ways in which we can overcome this, because I think it does have a major bearing on the way the Foundation's budget was cut in the Reagan proposals. I don't think we've come up with a rationale yet that satisfies anyone.

Dr. **Fletcher**. Mr. Brown, I quite agree that we have not come up with a rationale that satisfies anybody on this problem of addressing technology. I do want to reemphasize that without an extensive reorganization of the National Science Foundation, the Foundation is not the appropriate place to put that role.

Mr. **Brown**. I'll take that as an endorsement of a technology foundation. [Laughter.]

Mr. **Walgren**. Thank you, Mr. Brown.

Mr. Weber?

Mr. **Weber**. Thank you.

Dr. Fletcher, I appreciate your point of view, which is I think, shared by a great many. And I appreciate your frankness in expressing it. Many of us, at least on my side of the aisle, however, have a great deal of difficulty voting for any budget that exceeds the Reagan proposals, to be equally frank with you, yet we share many of the concerns that you've expressed, particularly in terms of science and engineering education.

I understand that your position is that we should probably go above the Reagan budget in order to restore some of those cuts.

However, I'd like you to speculate with me in a more difficult vein; and that is, if we don't do that, and yet we would like to restore some of the money for science and engineering education, where, within the budget as it is proposed by President Reagan, might there be more flexibility?

The largest items, obviously, in the budget are mathematical and physical sciences, and the astronomical, atmospheric, Earth, and ocean sciences. And I realize that that is the core program of the Foundation. That is where they have done their best work, and that is top priority in the minds of the Director, the President, and this committee and everyone else.

Is there any give in those budgets?

Dr. **Fletcher**. Mr. Weber, unfortunately I am in the position of being able to answer quite frankly, since I am not beholden to OMB or anyone else. So if you don't mind, I'll feel free to answer that question.

I think that the natural sciences can be cut slightly. And I think they would survive slightly increased cuts. All three of them, I can't remember the exact titles, are amply funded. And small cuts beyond what were done are possible.

I am not sure about starting this ocean margin drilling program. I think it is a good program and well worth supporting, but it is going to be lots of dollars downstream. I wonder about the wisdom of starting that. I'd rather start some of the new equipment programs at this time, instead of that one.

I would guess that except for the equipment program and the science education program I think you ought to be able to get enough money from the three natural sciences and ocean-margin drilling to be able to at least partially restore the funds in the other areas.

Mr. **Weber**. As you pointed out, and I appreciate that response, there is relatively little cut out of the biological sciences. I expect that OMB and the administration will go for the physical sciences. What about that area? Is there any give there?

Dr. **Fletcher**. In the biological sciences, I think that is just barely keeping up with inflation. I may be wrong, because I haven't really studied this in detail. The social and behavioral sciences were cut too much, and I think that is related to the earlier problems I discussed.

There were a lot of criticisms by Members of the Congress, but I think that the NSF has responded to those and that the social and behavioral sciences are sound at the present time. I would increase—I would restore some of the cuts. I don't know whether I'd go all the way back to what was proposed, but certainly I would restore the important parts of social and behavioral sciences.

Mr. **Weber**. Another question on my mind—maybe you aren't prepared to answer this—but it seems to me that there is a consensus among at least many of us that there should be some more emphasis on science and engineering education. How much money is needed?

Dr. **Fletcher**. I don't think, Mr. Weber, a great deal of money is needed. There are two problems. One is engineering, support for engineering schools, and the other is education. The education is for the primary and secondary schools.

Mr. **Weber**. Why don't you take them separately, then.

Dr. **Fletcher**. The engineering schools do desperately need support. We are not training nearly as many engineers as we ought to be. This probably relates back to some problems when aerospace was cut, including NASA. But nevertheless, people aren't going into engineering, and we are ill-equipped to train them. And so I think that should be heavily supported.

I don't have a dollar figure, but I think the support for the engineering schools ought to be increased over what was presented.

In the case of science education in the primary and secondary schools, I think a redirection of that program is indicated. I really do think the emphasis should be on training the teachers, rather than, shall we say, curriculum studies and things of that sort. So I don't think that requires a huge increase in trying to restore the whole program.

Mr. **Weber**. A modest increase?

Dr. **Fletcher**. A modest increase in that program, and redirect it toward the training of teachers, rather than experimenting with students and the curriculum.

Mr. **Brown**. Would the gentleman yield to me at that point?

Mr. **Weber**. Certainly.

Mr. **Brown**. Dr. Fletcher, I am interested in your point about the relative priorities of training teachers and setting up a different curriculum. I'm reminded of our experience in the 1960's, when it was extremely important to do something about updating science curricula or science materials used in the elementary and secondary schools. And for that purpose the NSF conducted a major exercise involving the country's top scientists

Yet, it seems to me, and this concurs with your judgment, that a health elementary and secondary school system ought to be capable internally, if it had properly trained faculty and administrators, of maintaining and up-to-date curriculum on an ongoing basis without going through some one shot, rather substantial exercise to do it, which was the way we did it in the 1960's.

I wonder if your suggestion about the importance of training science teachers is intended to be broad enough to include training in methodology and the capability of maintaining an adequate science curriculum in the elementary and secondary schools; not just taking one that is handed to them by some outside source?

Dr. **Fletcher**. Mr. Brown, that is a difficult problem. In the 1960's the science and mathematics curricula were revamped, and I think well done, on the average. It had a good effect and a bad effect. The good effect was that people who were going into science did have better training because they got the fundamentals earlier on.

The bad effect was that the people not going into science never really learned how to apply that science and technology. They got some of the fundamentals, but not the overall picture.

Since we don't have a two-track system, by and large, in our primary and secondary schools, there is some question about the value of the program. I wouldn't want to go back and change those curricula. I think some good work was done. I would simply change the emphasis from curriculum development to teacher training.

Mr. **Brown**. What I am asking is, would you train teachers to be able to do their own curriculum development so as to keep abreast of the changes that are taking place?

Dr. **Fletcher**. Absolutely, sir. I think that was the purpose of the summer institutes for teachers; to modernize, or give the primary and secondary schoolteachers a modern view of science. That was done well.

Mr. **Brown**. Thank you.

Mr. **Weber**. I have one last question. Again, it is sort of a difficult one. But we read in the paper this morning about a CBO report that may indicate future budget cuts down the road. We don't know about that. It may not happen.

But if it does occur, we may have to deal with new cuts in the future. So looking toward the future, I notice you identified one program in the budget that you have some skepticism about—the ocean margin drilling program. Are there any other programs within that budget that you are not opposed to, but skeptical of?

Dr. **Fletcher**. Mr. Weber, I don't have any other specific programs, and I want to correct the word you used. I didn't want to say skeptical about the ocean margin drilling. I think that at a time of budget cuts that are severe, I wonder whether it is wise to start a large new program of that size.

Mr. **Weber**. Are there any other programs that may not be wise?

Dr. **Fletcher**. I think the only ones I've indicated are in the science education area where cuts are justified, but some elements should be preserved.

Mr. **Weber**. Thank you. I have no more questions.

Mr. **Walgren**. Thank you, Mr. Weber.

Mr. Dymally?

Mr. **Dymally**. Dr. Fletcher, I take it, as part of your responsibility with the transition team, you did not have anything to do with the budgetary recommendations?

Dr. **Fletcher**. It's hard to say, Mr. Dymally. We sent our recommendations in and they were persued by the appropriate people, and it is quite possible that the new OMB saw our report. But you know how that is done. They take your report and condense it down into two pages, with one-line items. And they probably took any negative comments that we might have made and used those, and any positive comments that we made they ignored.

So it is hard to say what impact, if any, the transition report had on the budget. But certainly any recommendations on budget cuts or augmentations were not lifted in their entirety and put into the OMB cuts.

Mr. **Dymally**. But the transition team did make some recommendations?

Dr. **Fletcher**. Yes, they did, Mr. Dymally.

Mr. **Dymally**. Dr. Fletcher, on page 8 I read:

> I and most of my colleagues do not believe that the National Science Foundation is a proper place or institution in which this responsibility should be vested.

When you talk about responsibility, you are referring to technology, I take it?

Dr. **Fletcher**. Yes, sir.

Mr. DYMALLY. Could you elaborate on that somewhat? Are you suggesting to the committee that technology ought not to be a primary responsibility of NSF?

Dr. FLETCHER. Mr. Dymally, all I am saying is NSF ought not to be the focus of this responsibility. NSF has a role to play in a healthy technology for this Nation, but since technology is heavily industrially oriented, I wonder whether NSF is the appropriate agency within Government.

Mr. Brown has proposed a National Technology Foundation, which has a different orientation than NSF. I am not sure that is the right way to go, either.

Another possibility is the Department of Commerce, although the Department of Commerce in the past has not done that sort of thing well. It's conceivable that might be the central focus. I am only referring to who has the primary responsibility, if any, in the Federal Government for healthy technology; that is, industrial technology in this country.

By the way, I should mention that as far as military technology is concerned, it is clear. It is only nonmilitary industrial technology, where it is not clear where the responsibility lies.

Mr. DYMALLY. Does it suggest or follow that you are not supportive of engineering education as part of the NSF mission?

Dr. FLETCHER. On the contrary, Mr. Dymally. I really think that that's a piece of the problem that NSF can handle, and handle well. But that is not the overall problem. The overall problem is developing new technology, investments in research and development by industrial enterprises, transfer of technology from the science and applied science area into technology to be used in capital investments. All of that is part of the problem. That should not be in NSF. But NSF does have a role to play and the one you mentioned is definitely part of that role.

Mr. DYMALLY. Finally, the Japanese Government is investing some $15 billion in start-up money for technology. Would it not be the appropriate time now for Congressman Brown's proposal to be presented by, let's say, members of your transition team to the administration for review? Because we have two Mohicans left, food and agriculture and technology.

At the rate we're going, we may lose high technology to the West Germans and to the Japanese. If Government does not take a role, and I suspect that's been a trouble with our economy—we have taken the position, especially the embassies overseas, that they don't want to get involved with the business sector, and that businessmen are almost looked on as foreign agents, as opposed to the Japanese who are lobbyists for the Japanese industries.

And it seems to me, considering the private sector orientation of this administration, it might be appropriate for us to begin to look at this proposal seriously.

Dr. FLETCHER. Mr. Dymally, I quite agree with everything you just said. I think we are receiving more and more competition from not only the Japanese, but the Europeans. I do think we are dealing with that reasonably well, as far as aircraft are concerned. We continue to be competitive, and that is because of the NACA, which is now part of NASA. I think it is a proper question that this Congress should address.

Last year I made the suggestion, and I think mostly seriously, that perhaps the Congress ought to take a look at this overall problem and decide to not only have hearings, but to bring in professionals and deal themselves with this problem of what should the country do about restoring its technological leadership.

I particularly referred to things like computers and electronics. That seems to be where the new thrust is coming, and I think even some of those of us that are involved in industry are quite worried about this new competition.

Mr. **Dymally**. Thank you, Mr. Chairman.

Mr. **Walgren**. Mr. Gregg?

Mr. **Gregg**. I have no questions.

Mr. **Walgren**. Thank you, Mr. Gregg.

Dr. Fletcher, I'd like to explore a little further. In response to Mr. Weber, you indicated that the core programs could take some slight cuts. Our problem is how to get those two ends to meet.

Members on both sides want certainly not to be excessive in our funding. Some of us are not quite constrained to the Reagan number. But the problem I have is what do you mean by slight cuts? The question I'm trying to get at is: Would you recommend that we go somewhat over the Reagan number?

And in order to talk about that, let's talk about slight cuts in those core areas. The total increase in the core programs under the Reagan number is approximately $70 million for fiscal year 1982.

And there has been some thought that the minimal program that we should do in science education would be perhaps about $50 million.

Dr. **Fletcher**. Maybe half that.

Mr. **Walgren**. I see. So you would not need, in your view, quite that amount?

Dr. **Fletcher**. As I recall, it was x'd out completely, so half of that is better than none.

Mr. **Walgren**. Last year the number was 80 million, and—let me just finish my thought process and perhaps you can respond.

If we assume 50 was a minimal number to keep a significant effort going there, and if you assume that 20 was a minimum number for instrumentation, then those two would take up the slight cut, at least to the extent of absorbing the proposed increase in the core areas, without having anything left over to add to the behavioral and the social science programs.

Behavioral and social were reduced by 26 million.

So we would be looking for an additional 26 million even after finding $70 million for education and instrumentation. So that that Reagan number seems awfully tight. What I'm asking is, would you recommend to the committee that we live under that Reagan number?

Dr. **Fletcher**. Mr. Chairman, I don't want to be misread. I was only asking the question from the other side of the aisle. "What would I do if I were held to the Reagan budget?" I definitely think you ought to come up from the Reagan budget if you possibly can. I think cuts in the budget are required, but I think you're cutting off your own future when you start making too large cuts in the science and technology area. So I wouldn't recommend staying within that budget at all. How much I would increase and so forth, I really can't get involved in those details.

With regard to your number of 70 million, I don't happen to remember that. But I would guess a fraction of that could be placed at least to keep some of the science education programs alive and to make at least a modest increment toward instrumentation and equipment. But I can't give you the exact numbers. I'd be glad to go home and work it. But I'm not a panel, I'm just a person. [Laughter.]

Mr. **Walgren**. And it is your recommendation that we maintain the social and the behavioral to the same intensity that we maintain the mathematical and the physical?

Dr. **Fletcher**. When you say "the same intensity," I would say approximately to the level of last year's budget. I wouldn't want to go much below that.

Mr. **Walgren**. Could you add any detail to what you mean by "slight cuts"? Considering inflation, if we were to maintain that level funding, that would imply a reduction of effort in the range of 10-percent. Is that the range that you feel comfortable with in the "slight cut" description?

Dr. **Fletcher**. I think, Mr. Chairman, we're getting down close to details. But I think a 10-percent cut is a little more than I would feel comfortable with. However, I think the cuts made in the STIA and some of the cross-directorate programs, except for the equipment program, I wouldn't quarrel with those.

And I mentioned the ocean margin drilling program. I think that could be looked at.

I think there are funds adequate to come up with approximately the same budget that we had last year, without any 10-percent larger cut. And the Foundation I think can survive, if not be happy. That's about the position everybody else is in.

Mr. **Walgren**. Anything further?

Mr. **Weber**. I just want to follow one more point up. I do understand your position. I appreciate your responding to my questions even though we don't necessarily come to the same point of view on what should happen to the overall budget level.

But I'd ask you to make one more judgment for me. My view is that if we don't have the option of restoring all the cuts that we would like to have restored, we have to make some difficult decisions. If you were to make a comparison between the necessity for restoring cuts in the engineering and educational area and the behavioral and social science area—Which has the higher priority in your mind and why?

Dr. **Fletcher**. In my mind I have a very big prejudice, because I come from the natural science areas, so I would certainly favor the natural sciences over the social and behavioral sciences. I, however, have to add, quickly, the size of the cut in the social and behavioral sciences was much bigger than I would have made. I think they need to be supported.

Heavens, economics and all the controversy that's going on, it's about time we got down to some fundamentals in economics. That certainly should survive and so also should behavioral problems.

Research needs to be done. Even though they're not hard sciences, they need to be pursued. I wouldn't cut them anywhere near as much as they were cut.

So, I would put the priority on the natural sciences, but not quite such a distortion as is proposed.

Mr. **Weber**. Thank you.

Mr. **Walgren**. When you say "put the priority on the natural sciences," would that mean science education?

Dr. **Fletcher**. And engineering.

Mr. **Walgren**. Prior to behavioral and social?

Dr. **Fletcher**. Yes, Mr. Chairman.

Mr. **Walgren**. Well, we certainly appreciate the candor that you've given us. You've struck a lot of very sympathetic chords in me personally, and I think with some of the other members on the committee. You've given us a real, I think, ability to talk among ourselves, knowing that there is some informed judgment behind those kinds of lines.

Thank you very much, Dr. Fletcher.

Dr. **Fletcher**. Thank you, Mr. Chairman; my pleasure.

Mr. **Walgren**. The next witness is Dr. Allan Bromley, president of the American Association for the Advancement of Science. Dr. Bromley is Henry Ford, professor of physics at Yale and a director of Wright Nuclear Structure Laboratory, a Fellow of the American Academy of Arts & Sciences, and holds other positions in the science community that recommend him very highly to us and society as a whole.

We appreciate your coming very much, Dr. Bromley. Let me say that any formal written statement you might have will be made part of the record as a matter of course. And you may summarize in any way you wish.

Please proceed.

[A biographical sketch of Dr. Bromley follows:]

D. Allan Bromley

President, American Association for
the Advancement of Science

D. Allan Bromley (physics), 1926; B.Sc., 1948. M.Sc., 1950, Queen's University; Ph.D., University of Rochester, 1952; M.A., Yale University, 1961; Dr. Nat. Phil., University of Frankfurt, 1978. With Yale University since 1960; Henry Ford professor since 1972; director, A. W. Wright Nuclear Structure Laboratory, since 1963. Previously with University of Rochester and Atomic Energy of Canada, Ltd. Fellow, American Academy of Arts and Sciences; Governor General of Canada Metal, 1948; National Research Council fellow, 1952; Guggenheim fellow, 1977-78; Humboldt fellow, 1978; Benjamin Franklin fellow, Royal Society of Arts, 1979; Council, American Physical Society, 1967-71; chairman, Physics Survey Committee, National Academy of Sciences, 1969-73; chairman, Office of Physical Science, NRC, 1975-78. Vice president, International Union of Pure and Applied Physics; chairman, National Science Foundation committee to review university based nuclear science laboratories; chairman, CSCPRC Delegation in Nuclear Science to China; U.S./U.S.S.R. Working Groups on Science Policy and on Research on Fundamental Properties of Matter. AAAS activities: chairman, Section on Physics, 1978; Council, 1979; President-Elect, 1980; President, 1981.

STATEMENT OF DR. D. ALLAN BROMLEY, PRESIDENT, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Dr. **Bromley**. Thank you, Mr. Chairman.

I wish to begin by expressing to you and members of the subcommittee my appreciation for this opportunity to speak to you.

The country, I think we all agree, needs a revitalized economy and substantial economic growth. This is something which I believe the great majority of scientists and engineers in this country would support firmly.

Our economy has stagnated over the last decade. And although there can be disagreement among people of good will and great ability as to the exact causes of the stagnation, the fact is that our productivity gains have not kept up with our competitors in other industrialized countries. The numbers are dramatic when we compare ourselves with Western Europe and with Japan, for example.

I take it as a central thesis that a robust national effort in research and development is fundamental to any strategy for economic growth. Unfortunately, it is only rather recently that this role of research and development in economic growth has received detailed study by economists.

At the 1977 Annual Colloquium on Research and Development, sponsored by AAAS, however, it was reported to us that technological advance, the growth of knowledge, has been second only to the labor supply increase as a major source of U.S. economic growth over both the short and the long run since 1929.

My colleague at Yale, Bill Nordhaus, at that time a member of the Council of Economic Advisers, told AAAS in 1977 that most economic analysts were convinced that "the role of research and development in technological change in the economy is paramount."

Despite this apparent major consensus, it does not follow that the private sector will necessarily allocate optimal resources to research and development in all the areas that are of national interest. There are several reasons which explain this and which form the basis, I feel, for the absolute necessity for large-scale Federal support of R. & D.

First, there is the fact that the overall benefits to the Nation of much, though not all, long-range research and development certainly exceed the benefits to the organization that paid for it. This is going to lead inevitably, I feel, to underinvestment by the private sector in research and development and, very particularly, in basic or long-term undirected research.

A second reason is the fact that, by its very nature, research and development is intrinsically high risk. This, again, will limit private sector investment.

Third, in agreement with Hayes & Abernathy of Harvard, I feel that current management philosophies in this country, with their emphasis on short-term evaluation and payoff, mitigate against significant investment in long-term R. & D.

Finally, in some of the most frontier areas of science, the scale of instrumentation—telescopes, accelerators, you name it—required to reach the frontier is such that it puts them beyond the scope of all but perhaps the very largest private sector organizations.

This leads me then to the very clear conclusion that Federal support for R. & D. has been, and will continue to be, a very important investment in our national future. The overall benefits I believe to be very large.

It is our responsibility, I believe, in the scientific and engineering communities, to bring this relation to the attention of decisionmakers and the general public. We are convinced that research and development should be supported in this country on its merits as a long-term investment and not because of pressure from any special interest group.

When we look at the spending for research and development in the United States, the numbers are large. For the current year our national effort, about equally divided between public and private sources, comes to about $68 billion, or about $295 per citizen.

But you cannot examine numbers of this size in isolation. As is pointed out in the science and technology report of the commission on the agenda for the 1980's, "The sheer size of the U.S. economy results in larger R. & D. expenditures than those of other countries."

But taking these data in comparative perspective raises serious concerns about international economic competition. What are some of these comparative perspectives?

First of all, it has been emphasized again and again—and it bears emphasis—that since the mid-1960's the apparent increases in funding for R. & D. in this country have essentially all been taken up by inflation, and we have been on a flat-funding scenario.

Second, if we look at the 1978 Science Indicators, as published by the National Science Foundation—on page 10—and I include this as an appendix to my formal testimony—we see that there is a stunning difference in the pattern of investment in research and development in the United States and in some of our major international competitors.

We contribute far, far less of our total R. & D. expenditure to the search for new knowledge than does Japan or West Germany, for example. The reason is probably obvious and follows from the material that I provide in my appendix. It is worth noting that in recent years Japan has only allocated 2 percent of Government research and development expenditures for defense, West Germany about 12 percent, France 30 percent; whereas we have been investing about 50 percent of our R. & D. funds in defense spending. And our percentage in this area is increasing.

So we, in fact, are carrying much of this defense load for much of the western world.

Moreover the expenditures on R. & D. in this country, considered as a percentage of our Gross National Product, has been declining steadily since the mid-1960's, whereas the equivalent number has been going up rather dramatically in Japan and in many other countries.

Finally, investment by U.S. industry in research, as a percent of U.S. industrial sales, decreased by about a third between 1968 and 1980.

Such numerical comparisons are disturbing. They provide some insight into what is happening. But I would like to provide you with a slightly different view.

As a consequence of, on the whole, enlightened and certainly generous support by the U.S. taxpayer—acting through groups like yourselves, Mr. Chairman—we still have in the United States what I consider to be, overall, by far the strongest scientific and technical establishment in the world. This strength is in danger, and its continuance seems to me to depend on three important factors. These factors are:

First, that we must have enough imaginative, creative, people active in a broad variety of scientific and engineering disciplines. And we already have severe personnel shortages in these areas in this country.

Second, we must have modern, competitive facilities with which these people can work.

And third, we must have an adequate flow of some of the best young people in our Nation into these fields if we are to maintain our future.

There are real problems here, as I have already noted. I mentioned the severe shortage. It is getting worse, at least in the physical sciences, mathematics and engineering, and it is going to get much worse before the end of the 1980's.

The flow of young people into science and engineering I consider to be ominously inadequate, and in many places and in many areas our facilities have become noncompetitive in a world sense.

I am going to return to these points a little later, so if you will please bear with me, let me summarize thus far by simply noting that despite very extensive R. & D. funding, our investments are declining relative to those made by others, and given the technological successes and momentum of our international competitors we can ill afford to continue a no-growth policy in research and development over the long term.

We are also convinced that science and engineering education is an integral part of our scientific and technological structure in the United States, and that here again we have reasons to be very concerned.

In discussing science education I have included, with my testimony, a resolution that was adopted by the AAAS council at our annual meeting in January of this year in which we dedicate much of our activity, resources and effort for the next several years to trying to improve what we consider to be a very damaging decline in our educational quality and quantity—particularly at the precollege level.

Beyond this general concern it may be useful for discussion purposes, if I divide our educational enterprise in the United States into three broad categories: Graduate education, college education, and precollege education.

In the graduate field I think that I can say, without much question, that U.S. graduate education still sets the goals and standards by which world activity is measured. Our problem is that this strength is also in jeopardy because we find ourselves frequently working at the graduate level with research instrumentation that is technically obsolete, and usually one and frequently two or more decades old.

The result is that we are all too frequently engaged in an uphill competition with our friendly competitors abroad and, moreover, we are not attracting an adequate number of young people into science and engineering at the graduate level.

If I turn to the college area, we find peaks of acknowledged excellence, worldwide acknowledgement of excellence. But also we find valleys of much lesser quality. But again, I would have to say that if we average over the entire spectrum here in the United States I believe that we are competitive with any other nation in the world. At the college level however, the spread in quality is much larger in the United States because there is much less central control.

There are, however, serious problems, looming at the college level. Faculty members in the sciences and engineering are increasingly being drawn away to industry because of more attractive salaries and more attractive working conditions. Teaching instrumentation is aging; it is becoming obsolete. I feel that we are already damaging our ability to educate the next generation of scientists and engineers in a number of important fields. And we certainly are not attracting undergraduate students into the physical sciences, mathematics and engineering in anything like the numbers that even the simplest extrapolations show our Nation as needing in the future.

When I come to my third area, precollege education, I find the one about which I am most deeply distressed. Here I feel that we have seriously fallen behind the rest of the developed world. We face severe problems in both the quality and the quantity of science education being given to those few students who choose to take it at all.

Even more deplorable is the fact that a very large fraction of our students go through their entire secondary school experience without being exposed to anything significant in either science or technology. We are neither providing those students who may choose a career in science or engineering with adequate background for those careers, nor providing students with no special interest in these fields with the degree of scientific and technical literacy that will allow them to function effectively in a society such as ours that will be characterized by increasing technological sophistication and content. To the extent that these future citizens find it impossible to understand the issues involved, let alone participate in their resolution, the possibility potential for, alienation is all too evident.

I believe that it is extremely important for us to focus on the question of Federal support for science education. I think that the Congress was wise in amending the NSF Organic Act in 1972 to specifically include science education. And I think that it is neither realistic nor efficient for us now to expect the States to effectively reinvent the scientific and technological wheel and take over responsibility for science education. Furthermore, budget pressures will operate against the States staying current with the latest advances in rapidly moving fields.

It is important to note here that the NSF has never dictated to schools what they should teach. Rather, its purpose in science education has been to serve as a resource for the States and for the individual school districts which use NSF material—as they see fit—in their local educational programs.

There is yet another problem that bears attention. As in the case of college faculty, American industrialists have discovered, in that small and dwindling pool of qualified science high school teachers, a hidden resource. And they are hiring them away from the high schools at a rapid rate. Some 10 percent disappeared in industry last year from the ranks of science teachers in the high schools of this country.

And let me include a final and very central problem at both the college and the precollege levels. Quite apart from a teacher's ability to transmit the facts, if you will, of science and mathematics to students, important as this is, even more important is the enthusiasm, the challenge and the excitement that only a teacher who is in some contact at least with the frontiers of his or her field can really transmit.

This is the way in which some of our most able youth are attracted into the fields that are essential to our national future. NSF in the past has played a crucial role here in providing the support for summer institutes and for the other mechanisms whereby high school and college teachers were brought at least into contact with the frontiers of their science.

In concluding this section of my remarks I would argue that Federal funds for improvements in science and engineering education have the same long-term investment character as do those investments that we make for research and development itself. We must support both if we are to insure our future.

Let me then turn to President Reagan's NSF budget request. It should be said at the outset that, at the aggregate level, the magnitude of the proposed NSF reductions will not permanently damage the scientific and engineering enterprise in the United States. I base this judgment in part on reports that research and development in other Federal agencies has not been impacted as heavily as has been the case in the NSF.

In the current economic environment it is incumbent on all sectors of the society and the economy to undertake belt tightening. We recognize that this is an emergency situation and scientists and engineers are certainly prepared to share, along with other citizens, in the sacrifices that may be necessary to meet it.

We expect, however, that this slowdown in growth will be temporary and that there will be increased investment in research and development programs, by the Federal Government, in the years to come. This expectation stems from our belief that there will be a rediscovery—over the months ahead—of the essential role research and development plays in attacking the Nation's economic problems.

But we emerge from our study of the President's NSF budget request very puzzled and concerned about a number of the proposed sharp reductions and eliminations.

Let me list these briefly.

First, science education. I have already commented in some detail on this. I consider adequate support of effective science education programs at the Federal level to be a matter of very high importance and priority.

International programs are of particular concern to me as is the zeroing of the U.S. contributions to ICSU and to IIASA. I was pleased to hear, in Dr. Slaughter's testimony, that the ICSU support would still be there but now through the disciplinary divisions of the Foundation. Both of these—and many of the other—international programs are broad-gaged programs in international cooperation in science. Particularly as our foreign competitors move ahead of us in various salients and areas, it is essential, in our self-interest, that we maintain our contact with international science so that we at least know what is going on. This is certainly not the time to slam our windows on the world.

My third point concerns, programs aimed at solving science entry problems for minorities and women. I have already commented on current and growing shortages, at least in the physical sciences, mathematics, and engineering. And it bears emphasis that while over 50 percent of our citizens are women, less than 5 percent of those in these particular areas of science and technology are women. Women are clearly just as smart as we are. Our country can ill afford this continued wastage of this potential talent. And precisely the same arguments can be made for minority participation in science and technology.

I come then to social and behavioral sciences. The continuing support for the physical sciences and engineering in the Presdent's budget request for agencies such as NSF and DOE is a proper recognition, I believe, of their fundamental role in attacking many of the major problems now facing our society. But it bears emphasis that many of these problems, clearly identified in the public mind as being of science and technology—energy, the environment, health care delivery, to mention only a few—have the characteristic that almost in every case the science and technology is already in hand. It is the adequate understanding of the social science and the behavioral aspects of these problems that we lack and that stands in the way of effective progress. And it is for this reason, while recognizing that priorities must be drawn, particularly this year, we believe that the brutal reductions suffered by the NSF social science programs, and even more important the shock wave of uncertainty and confusion that these reductions have already engendered in the corresponding communities, will have a very serious negative impact on the effectiveness of our national response to many of our most pressing problems.

It may well be that a new balance among the sciences may be called for as we move forward to address these and other problems. But we would urge that a more gradual transition to this new equilibrium, whatever it may be, would have the great advantage of preserving at least those aspects of the social and behavioral sciences that will be absolutely essential in our future.

Intergovernmental science and technology. While the Federal Government, as early as 1940, accepted the fact that research and development was essential to national concerns, this realization has come comparatively late in the 1970's, to State and local governments. And NSF has played a very catalytic role in bringing about this realization.

To eliminate the programs that have been built up without any transition would destroy these fledgling capabilities. The kind of capabilities that I have in mind are those that took almost 70 years to devise in the Agricultural Extension Service.

In view of some of the discussion here this morning, I think it is worth noting that at least in part as a result of the activity of these Services a rather remarkable situation holds in U.S. Agriculture. Something under 5 percent of our 230 million citizens are engaged in agriculture; yet they feed us and much of the world. In striking contrast, over 80 percent of China's roughly 1 billion citizens are also engaged in agriculture, and still their situation is precarious. Two consecutive bad harvests could lead to disaster.

Finally I come to a topic that has been much discussed in these hearings—instrumentation. I referred earlier to the serious condition that our graduate university laboratories are encountering because of obsolete instrumention. This really must be corrected in the near future if we are to maintain our standards of research excellence. And there is indeed a high risk of losing our place at the research frontiers in a number of fields if we defer this initiative for any significant time.

I want also to emphasize that this problem is not in any way limited to our graduate programs. It is also present in our colleges and in our high school programs.

Here it is teaching and demonstration equipment that is required. All too frequently we find ourselves teaching with beautiful brass and mahogany instruments which bear no resemblance whatsoever to the instrumentation that characterizes the frontiers of our fields. And yet much of science and technology rests on elegant and exquisite measurement.

Finally, let me emphasize and reiterate the peculiar need that research and development has for reasonable stability in funding patterns. This applies equally to programs in scientific and engineering research and in science and engineering education.

Stop-and-go approaches, strong oscillations and discontinuities are, first of all, very inefficient. much research, much educational development dies on the vine. One of the very important aspects here is that some of the very best people involved, both in the research and in the educational enterprises are the first to become discouraged and leave. And research teams are very fragile. Once they are dispersed it is literally impossible to bring them together again.

Finally, then, let me conclude with a few comments on possible recommendations for action.

I would begin by restating one of my opening remarks. Given the need for significant, dramatic, economic initiatives, research and development clearly cannot escape temporary reductions or slowdowns in growth at least this year. But this does not in the slightest change the case for R. & D. We obviously must balance our priorities in the light of the larger economic issue. Indeed, it seems to me, without pretending any political expertise whatever, that in the current public climate it will be difficult for any of you or any of us to expect substantial increases beyond the President's budget request. Therefore, I would not suggest large increases in the proposed NSF budget totals for fiscal years 1981 and 1982.

At the same time, however, as I pointed out earlier and as I list in my testimony, there appear to be a number of local disaster areas, within the overall NSF requested level, and I hope that this subcommittee and the Congress will undertake a close review of them to consider redirection—and hopefully some small augmentation—of the total NSF budget to bring about the necessary relief that I have discussed above.

I think it is quite possible to agree with, and in fact totally support, the President's overall economic objectives, yet differ on the exact mix of program elements.

In conclusion I should like to reemphasize my belief that during the months ahead the fundamental worth, and in particular the long-term investment character, of research and development will become evermore evident. I expect that this recognition will be reflected in future actions of the administration and the Congress and that the current pause in R. & D. growth in the areas that I have discussed here will be temporary.

Mr. Chairman, I have much appreciated this opportunity to speak to you and to your colleagues on what I and my AAAS associates feel to be matters of great importance to the country.

[The prepared statement of Dr. Bromley follows:]

Statement by

DR. D. ALLAN BROMLEY

President

American Association for the Advancement of Science

on

The Fiscal Year 1982 National Science Foundation

Budget Authorization

Before the

Subcommittee on Science, Research and Technology

Committee on Science and Technology

U. S. House of Representatives

Rayburn House Office Building

March 17, 1981

Mr. Chairman and Members of the Subcommittee:

Introduction

Thank you for the opportunity--and challenge--of appearing before you today as you conclude your hearings on the NSF budget request for Fiscal Year 1982.

This morning I shall comment briefly on the state of science and technology, including science and engineering education. Also, while I do not plan to discuss specific budget amounts for various NSF programs, several general comments and recommendations are offerred for your consideration.

But first, let me say just a few words about the American Association for the Advancement of Science--or the AAAS as it is commonly known. We have as members about 132,000 scientists and engineers; as affiliates we have about 283 other scientific, engineering and technical societies and organizations--with a total membership of around 5 million. AAAS publishes the journals Science and Science 81, the latter with a circulation of about 750,000. The Association is also active in a broad variety of public policy and public understanding of science activities.

Need for a Revitalized Economy

Mr. Chairman, the country needs a revitalized economy with substantial economic growth. I believe the overwhelming majority of scientists and engineers in the United States support this objective.

The U. S. economy has stagnated over the past decade. Although men and women of good will and great intellectual competence might disagree on the causes, the fact is that productivity gains have not kept up with our competition in other industrialized countries.

In order to reestablish the desired growth for our national economy, it is likely that a number of incentives will be required like some of those discussed in the context of the Reagan economic program. Some of these incentives will impact research and development programs in a favorable manner. An example is the proposal for accelerated depreciation for capital equipment used in industrial R&D, recently announced by the Administration as a part of its program.

A robust national effort in research and development is fundamental to a strategy for economic growth.

The role of research and development has received increasing attention by economists seeking to understand the reasons for economic growth. At the 1977 annual AAAS Colloquium on Research and Development it was reported that technological advance, or the growth of knowledge, has been second only to labor supply increases as a major source of economic growth over both short and long periods since 1929.

It is not at all difficult to identify truly impressive examples of the high payoff of R&D. The rate of return on hybrid corn R&D is estimated at over 700 percent; all agricultural R&D investments are said to have a median rate of return of about 100 percent.

My colleague at Yale, economist William Nordhaus, at that time a member of the Council of Economic Advisors, told the AAAS in 1977 that most analysts are convinced that "the role of research and development and technological change in the economy is paramount." Yet, despite this major consensus it does not follow that the private sector allocates optimal resources to R&D in all areas of national interest. Two major reasons explain this and provide a basis for large-scale federal support of R&D.

A rationale for public support of research and development

First, there is the fact that the overall benefits to the nation of much--but not all--long-range R&D exceed the benefits to the organization that paid for it. Competitors benefit from corporate R&D investments by using to their own benefit the new knowledge generated. Further, consumers benefit from lower prices, so that the benefits of successful R&D do not flow solely to increased corporate profits. As a result, and as it has been demonstrated over time, there is good reason to believe there is and will continue to be underinvestment by the private sector in R&D--and especially in basic research.

A second major reason for the special role of the Federal Government in R&D arises from the highly risky nature of R&D investments. One cannot be sure that any one research effort, or any small group of such efforts, will pay off. However, like life insurance, probabilities of success almost become certainties when the aggregate of R&D projects is very large. Private investment in R&D--particularly of a long-term nature--are frequently discouraged by high risk considerations.

This leads to a clear conclusion that federal support of R&D has been and will continue to be an important investment in the future. The overall benefits appear to be large. It is our responsibility in the scientific and engineering communities to bring this relationship to the attention of decision-makers and to the general public. We feel R&D should be supported on its merits as a long-term investment, not because of pressure from a special interest group.

The amount of U. S. Investment in research and development has been and remains substantial--although there are problems.

When one looks at total R&D spending in the United States, very large numbers are encountered. For the current year, the national R&D effort--public and private--comes to about 68 billion dollars--or about 295 dollars per person. Yet, such large numbers cannot be examined in isolation. For example, as recently noted in the *Science and Technology* report of the Commission on an Agenda for the Eighties, "the sheer size of the U. S. economy results in larger R&D expenditures than those of other countries," but "taking these data in comparative perspective raises serious concerns about international economic competition."

What are some of these comparative perspectives? Let me mention several.

- While other nations have experienced real growth in R&D, the apparent increases in the U. S. reflect only inflation. In constant dollars we have been on a *flat* plateau since the mid 1960's.
- As shown on page 10 of *Science Indicators* for 1978, there is a stunning lack of investment in the advancement of knowledge by the U. S. compared to our major European allies and Japan. (Appendix 1)
- This observation relates directly to the fact that, as a percentage of GNP, total R&D spending in the U. S. has declined steadily since the middle to late 1960's--while the comparable number for Japan, West Germany and the U. S. S. R. has increased substantially.
- Investment by U. S. industry in research as a percent of sales decreased by about one-third between 1968 and 1980.
- In terms of international trade and economic competition, it may be worth noting that in recent years Japan has only allocated about

two percent of government R&D to defense, West Germany about 12 percent, and France 30 percent--compared to about 50 percent (and rising) for the U. S.

Such comparisons provide a disturbing insight about what has been happening to our investment in the future. But let me state my views in another way as well. As a consequence of enlightened, generous support by the American taxpayer, we still have, overall, the strongest scientific and technological establishment in the world. Continuing strength depends upon these factors:

- Modern, competitive facilities,
- Imaginative, creative people in a broad variety of scientific and engineering fields, and
- An adequate flow of our best young people into our scientific and engineering enterprise.

Above and beyond the statistical trends I noted earlier, however, as I look at these three factors I am troubled. We have severe problems and out world lead is in jeopardy; indeed, in some areas we have already lost our lead. What, then, specifically is wrong?

- In many areas and places our facilities are obsolete and non-competitive;
- We have current shortages of the right kinds of people; and
- The flow of young people into science and engineering is ominously inadequate.

But, I will return to these points a little later, so please bear with me.

In summary, despite large levels of R&D funding, our R&D investments are declining relative to others. Despite the lack of a statistical linkage between the leveling out of real growth in R&D since the late 1960's and our productivity slowdown, we feel confident in pointing to the need for continuing investment--public and private--in R&D for the long-range well-being of our nation. Given the technological successes of some of our international competitors we can ill afford to follow a policy of "no-growth" in R&D over the long term.

Science and engineering education is an integral part of our scientific and technological structure in the U. S.--and there are reasons to be concerned.

In discussing science education, first let me refer to a resolution on "Science and Engineering Education" which was adopted in early January, 1981 by the AAAS Council during our annual meeting. (Appendix 2)

Please note that we call for a full measure of effort to reverse the damaging decline of science and engineering education. Also, we point to the need for a new national commitment to excellence in science and engineering education. A basic reason for these positions can be succinctly stated: To expect scientific and technological progress while abandoning efforts at improving science and engineering teaching in our schools is illogical and a disservice to the Nation's interests.

Beyond this general concern, it may be useful for our discussion if we divide the total educational spectrum into three broad categories: graduate, college, and pre-college.

Turning first to graduate education, I think we can say without much question that U. S. graduate science education still sets goals and standards and is substantially ahead of anything else in the world. The problem, however, is that this strenght is in jeopardy because we find ourselves working with instrumentation that is technically obsolete and usually one or two decades old. The result is that all too often we no longer are competitive with the instrumentation enjoyed by our major international competitors. So the strength is there, but it is in serious danger.

We find "peaks" and "valleys" when we turn to the second major component --the college area. We have "peaks" of excellence and, unhappily, we have "valleys" of lesser quality. However, if we average the college spectrum in this country, I believe, on the basis of all the evidence available to me, that we would be essentially competitive with a similar average taken in any other country in the world. The spread in quality in our country is considerably larger, however, because we do not have the degree of centralized control over college education that exists in most of the rest of the world. Yet, there are serious problems looming here: faculty members in the sciences and engineering are being drawn away to industry in large numbers because of far more attractive salaries. We may well be seriously damaging our capability to educate the next generation of scientists and engineers in a number of important fields.

When we come to pre-college education, we are in the middle of an area where I am most distressed, and where I feel that we in the U. S. have fallen seriously behind the rest of the developed world. There are severe problems in the quality and quantity of science education being given to those few who choose to take it at all. But even more deplorable is that a very large fraction of our students go through this entire period of their educational life without ever being exposed to anything significant in science and technology.

Among the high costs of this situation is that it will be very difficult for the oncoming generation of people to function effectively in a society characterized by increasing technological sophistication and content. To the extent that these future citizens find it impossible to understand the issues involved, let alone participate in their resolution, the possibility and potential for alienation are all too evident.

I feel that it is terribly important for us to bear down on this question of federal support for science education. I think the Congress acted wisely when it amended the NSF organic act in 1972 to stipulate that the NSF should "initiate and support basic scientific research and programs to strengthen scientific research potential and science education programs at all levels . . ." (emphasis added).

It is not very realistic to expect each State to "reinvent the scientific and technological wheel." Also, budget pressures will operate against them staying current with the latest advances on an individual basis. I think it is important to note that the NSF has never "dictated" to schools what they should teach; rather their purpose has been to serve as a resource for the States and individual school districts to use material as they see fit in local educational programs.

One last problem in the pre-college area is worth mentioning. Comparable to the college faculty move to industry, a significant number of the better qualified science teachers have also left for higher pay in industry. This presents a severe challenge in an area already beset with difficulties. NSF has in the past played a very important role in "upgrading" teachers of science at these school levels and things could only become worse if the NSF moves out.

In concluding this section I would argue that federal funds for improvements in science and engineering education have the same investment character as those for R&D. We must support such work to ensure our future.

Structuring good R&D budgets at the national level and within the private sector remains an art--not a science.

While, as I noted earlier, there are substantial resources allocated to R&D in the United States, there also are fiercely competing demands for them. In sorting out these demands and working out allocations that make sense, NSF and other institutions must cope with a number of factors--each of which could provide the basis for extensive debate. I will mention only these:

- Government supported versus private R&D;
- Basic research versus applied;
- Problem-oriented versus disciplinary research.

Knowledgeable experts have disagreed in the past and will disagree in the future on the best allocation of R&D resources. However, our non-centralized, multi-faceted decision-making system in this country has done a rather creditable job of allocating resources in the past. And given its unique position as a "balance wheel" in the panoply of science and engineering institutions in this country, NSF has in the past done a good job in allocating its resources. However, from what we know about the proposed budget for NSF, this traditional process was not followed in its preparation. Consensus building in decision-making is central to our Nation's scientific and technological strength; we should be cautious about adopting alternative strategies which disregard the views of major participants.

Reactions to the President's New Budget Request

As I said at the beginning, I do not plan to discuss specific budget numbers. Even if I were so inclined, which I am not, we have not had the time to examine every budget element. Having said this, I am prepared to give my general impressions about the budget request.

At the aggregate level, the magnitude of the reductions will not permanently damage the scientific and engineering enterprise in the United States. This judgment is based in part on reports that R&D in other federal agencies has been impacted less than research in NSF by the budget revisions. In the current economic environment, it is incumbent on all sectors of the society and our economy to undertake belt-tightening. Scientists and engineers are willing to participate along with other citizens.

We expect this growth slowdown to be temporary, and that there will be increased investment in research and development programs by the Federal Government in the years to come. This expectation stems from our belief that there will be a rediscovery over the months ahead of the value of research and development in helping solve the nation's economic problems. Please note that R&D can make a contribution to the solution of these problems but cannot alone assure their solution. R&D, to use terminology found in the mathematics classroom, provides a necessary but not sufficient contribution to the solutions that we all desire.

However, we are very puzzled and concerned about a number of the proposed sharp reductions or eliminations. Among these are:

- Science education--Earlier I stated our views on the importance of this area as an investment in the future. I view the adequate support of effective science education programs to be of the highest priority.
- International programs--Of particular concern are the zeroing of U. S. contributions to the International Council of Scientific Unions (ICSU) and the International Institute of Applied Systems Analysis (IIASA). Both are broad-guaged endeavors to foster

international cooperation in science. Moreover, as foreign science becomes more advanced and more competitive, it is imperative that as a matter of self interest we maintain close contact so as to know what is going on.

- Programs aimed at solving science entry problems for minorities and women--In keeping with a long-standing policy, the AAAS supports the full utilization of human resource potential in the pursuit of science. Programs to increase access to science and engineering by all--including women, minorities and the physically handicapped--are necessary if we are to draw on the talent of the entire population in the search for solutions to the problems which confront us all.
- Social and behavioral sciences--The continuing support of the physical sciences and engineering in the President's budget requests for agencies such as NSF and DOE is a recognition of their fundamental role in attacking many of the major problems now facing our society. But it bears emphasis that in many of these problems, clearly identified in the public mind with science and technology--energy, the environment, health care delivery--to name only a few, the physical sciences and technology are largely in hand; it is an adequate understanding of the social science and behavioral aspects that we lack and that stands in the way of effective progress.

For this reason, while recognizing that priorities must be drawn, we believe that the brutal reductions suffered by the NSF social science programs--and even more important, the shock wave of uncertainty and confusion that they have already engendered in these social science and behavioral communities--will have a very serious negative impact on the effectiveness of our national response to many of our most pressing problems.

It may well be that a new balance among the sciences may be called for as we move forward to address these and other problems; but we would urge that a more gradual transition to this new equilibrium--whatever it may be--would have the great advantage of preserving at least those aspects of the social and behavioral sciences that will be absolutely essential in the future.

- Intergovernmental science and technology--While the Federal Government as early as the 1940's accepted the fact that research and development were central to national concerns, the realization that there was a comparable potential for State and local governments came much later in the 1970's.

  NSF has played a key catalytic role in bringing about greater and more effective use of science and technology by State and local governments. Such activities have not been seen as federal "interference;" rather, they are viewed by those affected as supportive, imaginative, and important to strengthening State and local government. To eliminate these programs without any transition would destroy these fledgling capabilities--the kinds of capabilities I might add that took nearly 70 years to devise in the Agricultural Extension Service.

- Instrumentation--I referred earlier to the serious condition our graduate laboratories are falling into because of obsolete instrumentation. This must be corrected before too much time elapses if we are to maintain our quality standards of research excellence.

Deferral of this initiative carries with it a very high risk of losing our lead on a number of research frontiers. Besides the graduate problem, however, we face comparable inadequacies at the college undergraduate level and in high school teaching facilities. The NSF has provided limited but effective support for these areas in the past; total withdrawal would only exacerbate an already serious problem.

Finally, let me emphasize and reiterate the peculiar need in R&D for reasonable stability in funding patterns. This applies equally to programs in science and engineering education. "Stop and go" approaches, strong oscillations, and discontinuities are very inefficient; one can end up with partially completed projects of little use. Once research teams are disbanded and dispersed, it is quite impossible to reassemble them.

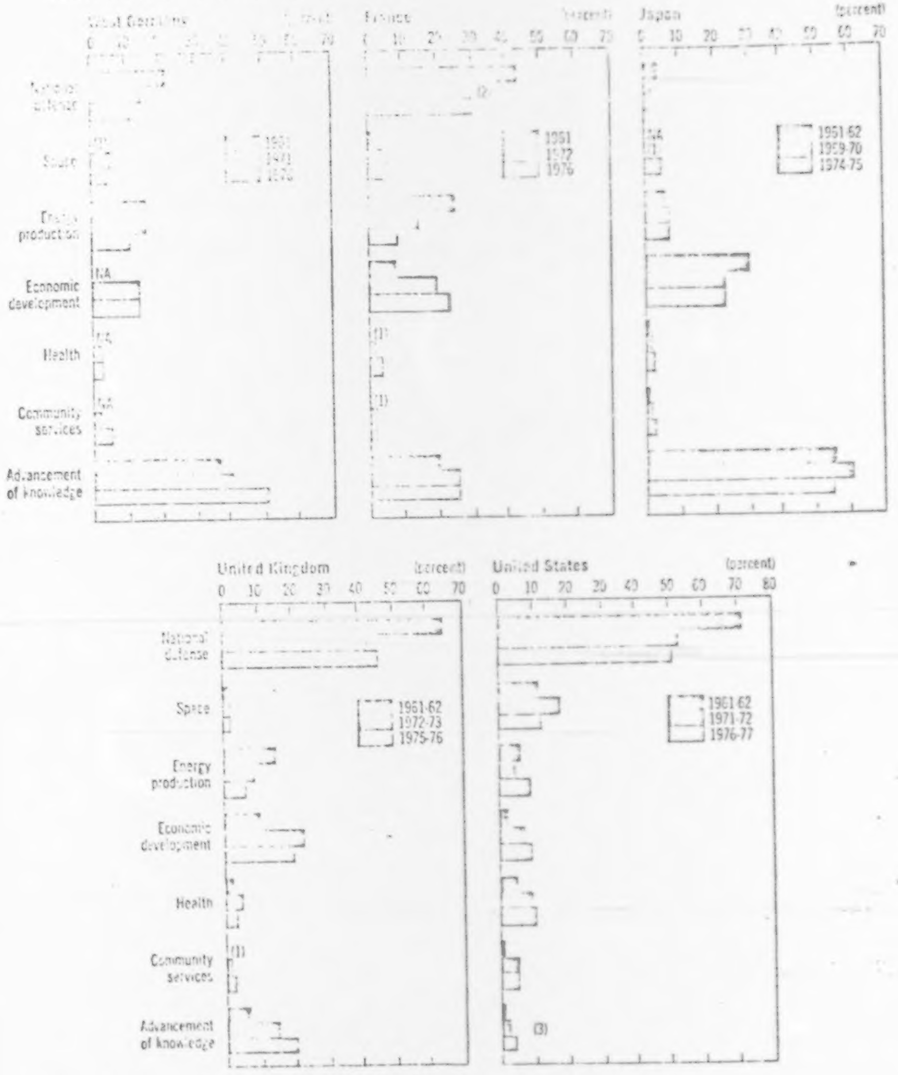
Recommendations for Action

Let me restate one of my opening remarks: given the need for significant, dramatic economic initiatives, research and development clearly cannot escape temporary reductions--or slowdowns in growth--at least this year. This does not in any way change the "case for R&D," but we must balance priorities in light of the larger economic issue. Therefore, I would not suggest large increases in the proposed NSF budget total for Fiscal Years 1981 and 1982.

Yet, as I pointed earlier, there appears to be a number of local "disaster areas" within the overall NSF requested levels. I hope the Congress will undertake a close review of these "areas" and consider redirecting the resources necessary to bring some relief. It is, I think, quite possible to agree with and support the President's overall economic objectives, yet differ on the exact composition of program elements.

In conclusion, I would like to reemphasize our belief that during the months ahead the fundamental worth--in particular, the long-term investment character--of research and development will become even more evident. We expect this will be reflected in future actions of the Administration and Congress, and that the current pause in R&D growth will be temporary.

Figure 1-5
Estimated distribution of Government R&D expenditures among selected national objectives, by country: 1961-77



[1] Less than 0.5 percent

[2] Later estimates indicate that this amount was about 32.0 percent

[3] General University funds are not included in the "Advancement of knowledge" category for the United States.

REFERENCE: Appendix tables 1-5 and 1-6

Science Indicators—1976

Appendix [illegible]

[illegible]

Science and Engineering Education

Whereas the advancement of science and engineering depends fundamentally on both the quality of education and an informed citizenry, and

Whereas the American Association for the Advancement of Science has a responsibility to foster excellence in the education of scientists and engineers while enhancing understanding of science and technology by the public at large, and

Whereas the scientific and engineering communities have long been concerned that serious and worsening deficiencies exist in science and engineering education, including precollege science education and college science education for citizens, and

Whereas a Cabinet-level report to the President of the United States notes that for the past fifteen years there has been a shrinking of our national commitment to excellence and international leadership in science, mathematics, and engineering, and

Whereas the American Association of Engineering Societies has adopted a position statement on engineering education and an action program,

Therefore be it resolved that the Board of Directors and Council of this Association

(a) Pledge this Association, in partnership with its affiliated science and engineering societies, to a full measure of effort to reverse the damaging decline of science and engineering education in the United States;

(b) Urge the President and the Congress of the United States to address the need for a new national commitment to excellence in science and engineering education for all Americans;

(c) Direct the president of the Association to convene a consultative conference of heads of affiliated societies with the aim of advancing science and engineering education in the United States in the 1980s; and

(d) Direct that a major theme of the 1982 Annual Meeting of the AAAS be "Toward a National Commitment to Educational Excellence in Science and Engineering for All Americans."

Adopted by the Council of the
American Association for the
Advancement of Science
7 January 1981

Mr. **Walgren**. Thank you very much, Dr. Bromley. That is a very good statement. It certainly points to science as a unique factor in the budget this year that deserves some special and even different treatment than some other portions of the budget.

Mr. Dymally?

Mr. **Dymally**. No specific comments, Mr. Chairman, or questions, except to say that I am impressed with Dr. Bromley's testimony.

Mr. **Walgren**. Thank you.

Mr. Weber?

Mr. **Weber**. I just have one question, Dr. Bromley. I would like to also compliment you on a remarkably concise and well-organized statement, something that even an amateur like me can follow. I appreciate that very much.

I just wanted to clarify one thing. As I understand your testimony, in trying to do some prioritization within the budget, your top priority area or the biggest problem area that you identified is young people going into science education at the primary and secondary school level. Dr. Fletcher a few minutes ago also told us that he thought there was a need for increased funding in the primary and secondary area. Is it safe to say that you feel that is the top priority in terms of restoring the budget cuts within the NSF budget?

Dr. **Bromley**. In terms of addressing the specific cuts in the NSF budget request, Mr. Weber, yes, I feel that the science education area has the highest priority for redress. And I do feel, and agree with Dr. Fletcher, that by a considerable margin our greatest weakness and the weakness that will cause us the greatest problems in the future is back at the secondary and elementary school level; not at the college and graduate level.

Mr. **Weber**. I think that's all the questions I have. Thank you, Mr. Chairman.

Mr. **Walgren**. Mr. Gregg?

Mr. **Gregg**. Are you saying that you would like to see us put back in the budget the total amount of science education dollars?

Dr. **Bromley**. No, Mr. Gregg. There are clearly, in any program, some areas that in times of stringency—such as we face at the moment—can be taken out. But it does seem to me that it does not make much sense to talk about going into the science education area in the National Science Foundation with less than about $50 million. That is the sort of target number I would have in mind.

Mr. **Gregg**. Where would you put that $50 million?

Dr. **Bromley**. Where would I put it? In terms of details, of course, I have neither the time nor the expertise to respond properly to you. But let me comment that the areas that I consider of importance and that I would include under the science education rubric are, first of all, the programs for teacher upgrading, teacher training, the summer programs of this kind. Then I have a very strong feeling of support for fellowship programs, because these are remarkably effective in attracting into those areas that will be of great importance to the Nation some of the best young people.

Over the years—over the last few decades—I have been troubled by the fact that fellowships based on abilities, fellowships based on demonstrated excellence have tended to disappear, and we have gone primarily to criteria of need. As important as these are in providing opportunities for those who would otherwise be excluded from access to our educational programs, I feel that we, as a nation, have been illserved by the loss of fellowship programs that are based on competitive demonstration of excellence. I say this because if we look back over history, people coming through the competitive fellowship programs have made disproportionate contributions to this Nation. I would like to see such fellowships put back into the NSF program.

Mr. Gregg. Do those two programs that you just mentioned total about $33 million?

Dr. Bromley. That's right. But I would also wish to include, my third component, in what I would consider the science education category, some component at least of the overall instrumentation program, because I do feel—and feel very strongly—that one of the prime limitations in our ability not only to train people, to give them the background, to give them the facts that are needed in scientific and technical education, is that we do not have good enough equipment. We lack the kind of equipment needed to attract young people into these areas as career fields, fields that students feel will be challenging and rewarding. We are going to pay a very large price as a nation for our failure to attract the appropriate fraction of our young people into scientific, engineering, and technological fields.

So I feel that it is the combination of upgrading the teachers, the fellowship program at both the college, and the graduate level, and the instrumentation at all levels, that make up the package that I would feel would come to roughly the $50 million.

Mr. Gregg. So you're talking $20 million for instrumentation?

Dr. Bromley. Yes; I would think that about right.

Mr. Gregg. Assuming you were going to stay within the Reagan budget, and I ask this as a hypothetical question, recognizing that you may not accept that as a valid assumption, where would you take the $50 million from in other programs of the NSF?

Dr. Bromley. First of all, let me say, Mr. Gregg, that one of the things that we have not mentioned this morning is the fact that I would certainly not ever expect to see the Department of Defense, for example, support science education as part of its mission. Here NSF has a unique mission. But DOD does, in fact, provide support, and I hope will provide more support, in the physical sciences, mathematics, and engineering. And I think that it is essential that we back off and take a broader look across the entire spectrum of the Federal agencies and their support patterns. As a physical scientist and with the greatest reluctance—particularly because I last year had the opportunity to chair a committee for the National Science Foundation that examined a large number of its university-based research programs, and know that these programs have been starved over the years, so there is no fat left in the physical science and engineering area in the NSF, I can assure you—but reluctantly, I would have to conclude that some redirection would have to come at the expense of the physical sciences, recognizing that this is an emergency situation. But I must emphasize the fact that there is no fat in these programs, and that we would be ill served, indeed, if we were to turn our backs on these very important areas; while some small redirection from the physical sciences and engineering might be possible this year it remains clear that it is in the Nation's interest that future support for these areas within NSF be increased substantially.

In fact, if you'd like a crude analogy, it seems to me that in many ways, our society and our economy are very much like a boat headed for rapids if not, in fact, a waterfall. And it seems to me that the physical sciences and engineering are what are required to get that boat turned around and at least going in the other direction. Once we get it turned around and going in the other direction, then, as I have stated earlier in my testimony, we have to have the social sciences and the behavioral sciences strong and available to help us chart the direction we really want to go. And we dearly will need Federal support for science and engineering education.

Mr. GREGG. I guess I'm not sure that I understood your answer.

Where do you think the $50 million should come from, if you're going to take it out of this budget and still maintain the Reagan dollars?

Dr. BROMLEY. Mr. Gregg, I simply have not had the time to look at the budget in detail and can therefore not answer in detail. I can only give you answers based on broad principle at this time. But there are three things that I would hope could happen. One is that I do hope that we would not have to be entirely restricted by the Reagan ceiling. Second, I think that more support of some of the areas of physical sciences that are very important and even of the social and behavioral sciences might well be picked up by the Defense Department, at least temporarily. It, after all, is scheduled for a $5 billion increase in its research and development funds.

And third and reluctantly, I can see on a temporary basis, some reduction of the NSF funds in the physical sciences and engineering. But I am in no position whatsoever, Mr. Gregg, to give you a detailed answer.

Mr. GREGG. How about the astronomical and atmospheric, and ocean science areas?

Dr. BROMLEY. I would share Dr. Fletcher's feeling that given the stringency of our present situation, the ocean-margin drilling program is one that—while I know that it is important to a great many people—I would tend to consider as a candidate program that you and others should examine for possible deferral.

Mr. GREGG. That poor program gets beat upon by everybody. [Laughter.]

Mr. GREGG. Thank you, Mr. Chairman.

Mr. WALGREN. Mr. Brown.

Mr. BROWN. No questions, Mr. Chairman.

Mr. WALGREN. When you say that you hope we would not be constrained absolutely by the Reagan budget as submitted, in terms of the overall effort, how do you weigh the impact of inflation on the NSF budget? If we stay with level funding, we really are taking a substantial reduction in effort. In your view, does the special urgency and the unique kind of contribution that research makes to our economy give it special weight in competing for Government dollars, and do you feel we would be cutting off our nose to spite our face, if we stayed with level funding, which would be a 10-percent reduction?

Dr. **Bromley**. Mr. Chairman, I feel very strongly that if we continue with a situation where we are either flat or dropping with inflation each year, we are doing great disservice to the country. I can give you a specific example from the studies that my committee carried out on NSF programs a year or two ago. It was clear that over a period of about a decade, relatively flat NSF dollar funding, coupled with growing inflation, had literally squeezed universities such as Stanford University and the University of Maryland, out of viable research activities in the fields we were considering. Such losses are very serious ones to the overall research program and health of the country.

Mr. **Walgren**. If we maintain effort, we would have to increase the present budget level by about 10 percent.

Dr. **Bromley**. Yes.

Mr. **Walgren**. Thank you very much, Dr. Bromley, we certainly appreciate that statement. And you, in addition to Dr. Fletcher, have given us some broader perspectives on the NSF budget. And I, personally, and I know the committee certainly appreciates it.

Dr. **Bromley**. Thank you, Mr. Chairman.

Mr. **Walgren**. The final witness is Dr. Phillip Handler, president of the National Academy of Sciences. Dr. Handler is a professor of medical science at George Washington University and a former member of the National Science Board and the President's Science Advisory Committee from 1964 to 1972. He has served in a host of other capacities with the national science community.

Dr. Handler, we're really pleased you could come and spend some time with us and share your views on where we're going with the NSF. Any formal statement, of course, will be made part of the record, and we would invite you to proceed as you feel most comfortable in discussion with the committee.

STATEMENT OF DR. PHILLIP HANDLER, PRESIDENT, NATIONAL ACADEMY OF SCIENCES

Dr. **Handler**. Thank you very much, Mr. Chairman, and gentlemen.

I regret that I have no formal statement. I did not know until yesterday afternoon that I would be here, so if you'll permit me, I'll take it from there. Very simply, sir, I find it very comfortable to simply associate myself with everything that I have heard from Dr. Fletcher and from Dr. Bromley. Those are precisely the sentiments which I would have committed to paper, had I the time and opportunity for doing so. I think the Nation would be well served in being attentive to their remarks.

The circumstances in which we the Nation find ourselves can be stated in somewhat oversimplified terms, somewhat as follows:

After World War II, our Nation found itself stronger, healthier, more vigorous, richer than it ever had been before, whereas, the rest of the world was in ashes. The consequence of that was a 20-year headstart into the modern era. And the more grayhaired among us found the way of American life during the 1950's and the 1960's very comfortable, indeed. We thought that that was America's special place in the heavens.

During that time, however, while we weren't quite aware of it, the rest of the world recovered, and slowly began to develop their own R. & D. enterprises, their own technological industries. Quite unexpectedly, when we took stock, we discovered we really were no longer quite the nation apart we thought ourselves. Our leadership of the scientific enterprise was somewhat challenged by the science of other nations. We're still in first place, but challenged. And our technological leadership has similarly been challenged.

It is the consequence of the latter, the invasion of our own consumer market by the products of technological industry overseas which has rocked us quite in this special way, which led Mr. Brown to conduct his hearings in this room now for several years.

It is within that context that the current rebudgeting of the National Science Foundation should give one pause. My problem, gentlemen, is not so much what was done, but how it was done. And the reason I find you to be inadequately served is the nature of the process more than its outcome. The process is such that with administrative discipline imposed on my colleagues from the National Science Foundation, it's very difficult for us to understand quite what the impact of the proposed rebudgeting will mean for the actual operations of their programs. They have done the very best that they could do under the circumstances.

I would not join anyone proposing an alternative specific budget for the National Science Foundation. Those who do that work at the Foundation, day by day by day are best informed as to what might be wise, were the Science Foundation simply given a new overall mark and told that it will have to forego whatever amount of money is deleted from the previous budget proposal and then bring back to you a new budget proposal that would assure the total strength of the enterprise, retrenching in a few places, if that need be done. But such an arrangement must make sure that we lose no ongoing capabilities. That we shouldn't do.

Very briefly, I would like to cover just a few of the points to which you have been discussing this morning, and then turn my attention to the international aspect of the program, because that is primarily what brought me today.

I would have a hard time, Mr. Gregg, establishing priorities among the areas which have been reduced in their funding. I am sure that the OMB struck the item for instrumentation of $75 million assuming that to be an easy thing to do, because it was a new program, a new start, and, therefore, deferrable with minimal damage. But gentlemen, the first discussion of that program that I can recall, took place in Guy Stever's office when he was director of the National Science Foundation. The fact that we would have to have such a program in due course has been known for quite a few years. On several occasions, the point has been made before this committee and before the Appropriations Committees. It is a very serious matter. $75 million is the barest beginning of that what program is intended to accomplish. If we're serious about science as an investment in the national future, if we really do understand that the Nation is going to have to live by its wits, and that those "wits" in our time means wise utilization of our scientific capabilities and their deployment, this is not the place to make a serious cut. I cannot find it wise to delete the item in its entirety.

All of us have read again and again about the situation of education in the secondary and primary school system. All of us have been disturbed that the SAT scores of students applying to college have been in a steady decline. I was shocked, however, recently by the finding that not only is the mean score declining, but the number of high scores is declining as well. The absolute number of high scores, scores over 600. I thought that the brightest students were making it through the system, regardless of the deficiencies of the system. That seems not to be true any longer. And that puts us in a very serious way.

There have been innumerable reports on what is wrong with school science. I happen to have brought one with me, a report which was prepared by a panel of our National Research Council last year and submitted to the National Science Foundation. It is only one of such. I confess, gentlemen, I don't know what is fundamentally wrong with school science. The national investment is enormous, and the output is very poor. And I don't really know why.

The role of the Federal Government is not to provide operating funds for the school system. It is, however, I hope, to provide funds which would catalytically enable the improvement of the quality of what is done and make that available to every school system in the country. We have been doing that. I cannot tell you how well the Science Foundation has been doing that of late. I did know in detail what it was doing in that regard in the 1960's.

But surely this is not the time to back off. The tenor of what Dr. Fletcher and Dr. Bromley were saying to you had to do with those young people who would later, after they emerged from the school system, participate in the development of new technologies, in the doing of new science, and in the teaching. I'm really more concerned today for the level of scientific and technical understanding of the average outgoing student from the secondary school system, because the important question is what will be the quality of the American labor force, and how can it perform in a world in which productivity in technological industry is the name of the game? In that regard we certainly look very bad by comparison with what is going on currently in Japan, Germany, and in the Soviet Union.

I don't know whether the Science Foundation education programs are adequate. If not, they should be made adequate. But that is a mission they should have. Walking away from it leaves no entity in the entire United States with that specific mission. That I think would be dreadful.

The next large proposed cut was in the social and behavioral sciences, I should remind you that the other place in the Federal budget where such sciences are funded explicitly is in the budget of the National Institute of Mental Health. There they have simply been zeroed for the fiscal 1982 budget. Some such matters may still slide into the Department of Agriculture budget, Mr. Brown, but by and large the explicit support of social and economic science in the recently revised budget proposal has been reduced to where there won't be very much such science in these United States. Given the fact that the only Nobel Prize winner in Pittsburgh, known to me, is an economist—He's the greatest hero the town has had since Honus Wagner or Dick Groat. [Laughter.]

I find that very remarkable. In a way, the chief argument one can offer is that if we had sufficient understanding of these matters, the very exercise in which you are engaged wouldn't be necessary. We would know how to make these calls as to what is valuable and what is less valuable. We wouldn't have been playing with the economy in such manner as to make obvious that we don't really know what is the quite correct thing to do at this moment. After years of appropriating funds for the whole of the Federal budget, we are about to suddenly turn around and engage in a large budget slashing exercise in the hope of turning our economy around.

Heaven knows, I share that hope. What I'm pointing to is the deficit in our understanding of how the system works, a deficit that led us into the large-scale kind of experimentation in which we're now entering. I hope it succeeds, but that we understand what we're doing is highly doubtful.

That's not, in any sense, perjorative. It is to say that the sophistication of the economic understanding and the social understanding of our society leave a great deal to be desired. I find it passingly strange, then, that at this time we should decide to abandon that attempt. I hope you'll not do that, certainly that you will not agree to delete the funds required to support the effort to evaluate the outcome of the huge experiment on which we are now embarked.

I'll not speak to the matter of women and minorities. I simply share what has been said here already.

Let me come, then, to what brought me rather explicitly—namely, the international program. First, I have to confess that I will appear to be in conflict—in conflict because almost half of the funds that are distributed through the international budget of the National Science Foundation are, in turn, moved to the National Academy of Sciences as they are distributed outward. Since I am steward of that operation, I am obviously in a kind of conflict.

On the other hand, I hope that I'm free to share what Dr. Bromley said about the comparative value of international scientific cooperation. It serves a variety of functions. It manages part of the process of making this one world. It is a kind of cultural interchange in which we simply must engage, an aspect of the ancient humanistic tradition of the West. Patently, it is to our own advantage to have a clear eye on what goes on in science and technology outside our own borders. No one can do it quite as well as the scientist who has gone overseas and is indirect contact with his international colleagues.

It's too late to learn about important developments when new technology crosses our borders and pays tariffs or when we read about it in journals. We should be au courant if we possibly can.

Then there are the ventures which can be only undertaken jointly. That's been one of the great glories of science in the last few decades—a dozen or so very large scientific undertakings which were truly international, truly cooperative on a large scale. For most of them, NSF has been the primary sponsor. They've been just extraordinarily successful efforts.

Given a marked reduction in this line item of the budget and without explicit directions as to what should be done under those circumstances, the staff of the Foundation finds itself in a terrible bind. There are only a few large program elements, and the simplistic choice is to either reduce all of them back proportionately pro rata or decide to abandon some and support the others as had been proposed earlier.

Two elements of that program couldn't possibly be treated in a pro rata fashion. These both consist in large part of dues payments, dues to the International Council of Scientific Unions and their components and dues to the International Institute for Applied Systems Analysis.

There are also the programs for exchanges with the Soviet Union and the East European countries and exchanges with China. The staff of the Foundation has made what I consider very wise decisions in these latter regards. I would not challenge them for a moment.

With respect to the International Council of Scientific Unions with its dues and the measures necessary for American support of that system, you should realize that funds were appropriated to the State Department for many years. At the Science Foundation's request, they were moved to the Science Foundation from the State Department.

After that transfer, the arrangement within the Foundation was the one which you heard described this morning—that is to say, the various research directorates of the NSF provided the funds that were used for this purpose. That was an annual internal battle.

You have to understand that there are dual purposes in these programs, if you will—the strictly scientific and the element which is international/political. They serve our international political benefits.

Those who make the decisions in the Research Directorates understandably place research first and do not look at the other value. They're not asked to. I hope they won't. Their job is supporting American science at its very best, and I hope they go right on doing that.

Unfortunately, therefore, they don't quite appreciate how support of the International Unions relate to the international scientific venture and to our own national interests. If indeed we mean to make these payments and support this elaborate network of scientific relationships, support them for the very reasons that Dr. Bromley enunciated, we should have the courage, the decency, to do it in a forthright fashion and say, "This is what we're going to do," Then the transactions should be visible so you will know that it is being done, and not buried inside those other accounts where it won't be noticed.

In their recommendation this morning, Dr. Slaughter and Dr. Langenberg weren't hiding their purpose. They were doing just what Mr. Gregg has been asking—what would you sacrifice in order to do this other thing? Implied in their recommendation was that they were willing to sacrifice just a little bit of the direct research support in order to make these other payments possible; that's what it came to. I could wish we would continue to budget for this item in a straight-out fashion, because we mean to.

My big shock, however, came this morning when I heard what they had decided with respect to the International Institute for Applied Systems Analysis. I was unaware of that decision until I heard it this morning. They not only admit some difficulties for fiscal 1982, but made a specific statement saying that we should resign from membership in that organization. That's a very difficult and complex decision.

It's in this regard that my conflict is most evident. The history of that organization goes back to Mr. Johnson's presidency. The original proposal was made by McGeorge Bundy, and it had to do with creating what was then called an East/West Institute—some place in the world where scientists from the West could sit down with scientists from the East and talk about problems of mutual concern with a minimum of tension.

It was Mr. Johnson who proposed that it be a nongovernmental organization. The principal reason for so doing at the time was that we didn't recognize East Germany. If we had had a purely governmental institution, then East Germany couldn't have been part of the enterprise. That's the reason the nongovernmental character was first proposed, and it was in that way that it was brought into being.

President Nixon strongly endorsed the creation of this organization, and it was he who instructed Mr. McElroy when he was Director of the Foundation, to go ahead with support of IIASA. Mr. Rogers was Secretary of State at the time, Mr. Rogers wrote a long memorandum to Mr. Nixon explaining where matters stood at the time, pointing out that at the time he had written it, the negotiations to create IIASA had been conducted by the academy with the full knowledge of the State Department.

I had spent 2 years negotiating with our Soviet counterparts all over the face of Europe. Originally the Soviets wanted the Institute to address only the methodology of systems analysis, whatever that be. I insisted that it either address real problems or we would not play. Finally, they agreed, and it was after that that the institution was born and brought into being at first, I believe, with about 10 or 12—I've forgotten—member national groups. It's now up to 17. It is located in Austria.

The negotiator for Austria at that time is now the Prime Minister, Kreisky, who was at that time the Foreign Minister. Austria has put up—I thought it was something over $10 million but I was told the other day it is now very close to $30 million for the renovating of the physical plant for the location of this institute. Sixteen governments other than ourselves have made very special arrangements in order to funnel Government funds through private bodies into this organization.

When you're saying that about an East European country, it's something of a farce, as you will recognize. The Soviet Academy of Science or East German Academy of Science is not really a private body at all; it's part of the Government. Nevertheless, that's the channel. But our NATO colleagues, our allies, have each made very special efforts in order to get this going.

As Dr. Slaughter remarked, IIASA is a success. It has met its tests. Scientifically the output has been at least adequate by all yardsticks, and it is ironic that we should do that, take such an action, in the week in which this book appears called Energy in a Finite World, the output of a study led by Wolfe Haefek of Germany, the program leader of this program of IIASA.

It involved several hundred people of whom, perhaps, a quarter were Americans. I do believe that this report will be the most influential study of the world's energy situation we will have for perhaps 5 years or so. Energy studies are cheap; they don't last more than 5 years. The rate of change is so great you can't rely on anything any longer than that, if you can rely on it that long.

But the dozens of energy studies we've had in the United States, including the big one by the Academy, all looked inwardly. There wasn't a single report analyzing the United States energy problems that I can recall, that took full cognizance of what was and would be happening in the rest of the world. This is the first one to make a really bold attempt to do that and I hope a successful attempt.

That is what IIASA was really created for. I can't say that this report justifies all the money we've put into it, but there are other reports and activities that have come out of that Institute as well, albeit none of them quite so unique and remarkable as this.

Most importantly, I shudder to think that in this room this morning an announcement is made which is going to reverberate through 16 national capitals. I don't know whether the State Department agrees with this evaluation. I don't know whether the National Security Council thinks that this is a good idea. I don't know how 16 ambassadors will react to all this, and I don't know what Mr. Kreisky is going to say when he calls President Reagan. It's a very complicated kind of decision, and I'm sure it should not be taken without full discussion of what this is all about. The political repercussions are at least as meaningful as the purely technical ones that would be lost to us.

Neither alternative scenario seems attractive to me. If, without U.S. support, IIASA simply ceases to be, all of our allies, whom we originally persuaded to join, will surely be wroth. So will the Austrians. Alternatively, the Soviets may see this as a way to convert IIASA to a Pan-European body, strengthening their relationship to West Europe in the absence of an American presence—and that seems even less desirable.

There's been a steady flow of distinguished Americans through that place. One won a Nobel Prize, Tjalling Koopmans, who thought so well of it that he turned over his Nobel Prize money to the Academy to support the International Institute of Applied Systems Analysis.

It's not a trivial place, and it doesn't engage in trivial activities, and it meets its original test. Every day, Americans, Germans, British, French sit down together with people from the other side of the Iron Curtain, and they talk about problems of mutual interest or concern with a minimum of tension. There's always some tension—you must understand that—but it's a minimum of tension, and it does work.

I would think that if it were possible, we'd improve on this mechanism and expand it rather than abandon it. In any case, if abandonment is what we're going to do, we'd better think about it very carefully, give long formal notice before we do so, and rock this boat gently, not just overturn it all at once.

In the world of international politics, long notice is the name of the game—adequate discussion. I hope we will behave accordingly if that is the way things come out. I do not mean that we should never reexamine this organization and our role in it; I think we should examine it very, very carefully, and such a recommendation would be in order at any time. However that is undertaken, that is the way it should be done. We shouldn't just suddenly, for reasons which have nothing to do with the primary purpose of that Institute and how well it's functioning, abandon it this abruptly.

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you very much, Dr. Handler. I appreciate that particularly.

Mr. Brown?

Mr. **Brown**. Could I yield to my other colleagues, Mr. Chairman?

Mr. **Walgren**. Mr. Dymally?

Mr. **Dymally**. No questions.

Dr. **Handler**. Mr. Gregg?

Mr. **Gregg**. No questions.

Dr. **Walgren**. I feel that you have underscored one of our problems—that is not so much what was done but how it was done. Certainly when it comes to viewing the role of people at NSF, we have to keep in mind that the position that they were put in did not give them very much opportunity to differ or to change the direction that the momentum was moving.

I really appreciate your coming on such short notice.

Mr. Brown, do you want to pursue some questions?

Mr. **Brown**. I would like to go back and focus, at this moment, on the international programs of the foundation which you commented on at such length. I share your concern about the termination of the funding for IIASA. I also have a concern with regard to some of the cooperative programs that we have with other nations, such as the nations of the Third World, the underdeveloped nations. And I would like a comment from you on this area.

Our performance for the past several years, and I can point to the past administration as well, has not been particularly good. We have proposed and then defaulted on our proposal for an international science and technological organization. We are now apparently backing away from the Law of the Sea Conference, which would have really done a great deal for the underdeveloped world in terms of providing resources for their own technological development. It may well be that the main link remaining is the joint programs of the Foundation, and they are being severely cut. Could you say a word or two about the possible repercussions of this, in addition to what you've said about IIASA?

Dr. **Handler**. Mr. Brown, I was in Venezuela last week, which is a developing nation, but one that can afford to pay for its development. Well, I guess we're paying for their development, somewhat involuntarily, perhaps. But the sense of uncertainty of what the United States really means about assistance with development was conveyed to me by the President, with whom I spent an hour last week; whether the United States really has a genuine commitment to assisting the developing nations.

I assured him we did, but I did it with a somewhat heavy heart. I wasn't sure whether we do or we don't. In truth, these are very small potatoes, the money in the NSF budget for working with the developing nations. And in fact, the support of development, per se, is not a mission of the Science Foundation. What it does do is provide support in a catalytic way for paying the American part of work that is done cooperatively with scientists in developing nations.

It builds bridges. It enables the scientific community in those developing nations to facilitate its own bootstrap operations, if you will.

I could wish we were more sure of ourselves. But if I were sure we meant it, it would help. It is perfectly true that we will find it hard to live with our success. We, one day, will have a world where we all sell refrigerators to one another, as it were; nobody knows how the economy of that world works. We wince a little bit with the success of such achievers as Japan, Korea, Taiwan, and Singapore, all of whom have so well invaded the American consumer market.

But our response shouldn't be to stop that process. Our response should be to redouble our effort to get on with the process internally in the United States.

The trick is to stay out in front. To be the real scientific and technological leader of the world. If you are such, you don't have to worry about those people breathing hot behind you. Let them have a share of the market. It won't hurt us a bit.

Mr. BROWN. This NSF program in the international field can fairly be characterized as foreign aid in the normal sense of the word?

Dr. HANDLER. No, sir. There is no foreign aid of any sense in that. Certainly no capital grants in aid. And the money is largely spent at home by and for American science.

Mr. BROWN. Let me go on to the other question that I raised at the beginning of the session this morning, to just give you an opportunity to make a brief comment if you wish. I am concerned about the way in which science programs for research and development are treated in different agencies of the Federal Government. I used the example of the agriculture research compared to NSF, and you brought up the matter of NIH.

Do you have any comments as to the factors which may have entered into the differential treatment of these various different aspects? Of course, obviously, we could include defense R. & D. here. I think we understand the factors that are at work there. But in general, with regard to programs which support university research as the ones that we're discussing do, how do you see the basis for the differential treatment that's been received?

Dr. HANDLER. I don't think I can speak to that fully, Mr. Brown, because to do so, one would have to do it with knowledge of the process inside the OMB, and I cannot pretend that knowledge. A series of actions taken across the Government, including some of those taken with respect to the Science Foundation budget, were perhaps initially motivated by the general task of reducing Federal expenditures for reasons which are all in the public domain. But the choice of what programs to cut was driven by social philosophy, in large measure, in many places, rather than by financial constraints.

The decision wasn't so much that we could not afford some of these small items, but rather that we shouldn't do some of those small items. That, I think, must be what accounts for the large slice against the social and economic sciences' budgets. That, I think, motivated the reduction in the proposed appropriation for science education, which follow the administration's intention to just get the Federal Government out of the education business. But I doubt that those who did this fully appreciate what the nature of the Science Foundation's actual program is.

I don't know who actually oversaw the process of looking at the agriculture research budget. They may not have realized that agricultural economics is buried in there somewhere. Maybe they did, but thought of it as in an applied sense. That may be the better answer.

We in the academy have had trouble with the agricultural department's research program for years. It was I who pointed out that all federally supported research in photosynthesis—at that time the major research in photosynthesis was being paid for by the National Institutes of Health, which I thought was absurd. There is an agricultural establishment and it is a very powerful establishment, indeed, and it protects its own.

Mr. BROWN. Thank you.

That's all I have, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Brown.

Again, on behalf of the committee, we appreciate your coming and sharing those thoughts on such short notice. We will take them under advisement.

Dr. HANDLER. Mr. Chairman, there is one thing I might have mentioned. Mr. Brown and I have both contributed to this sexy issue of Science Magazine this week, and I don't know whether he cares to have his letter in the record, but because I have an editorial which bears on precisely what you have been discussing this week, I would appreciate it's being included in the record.

Mr. WALGREN. We'll be happy to include that in the record at this point.

[The editorial follows:]

Pruning the Federal Science Budget

Appropriations for research fall within the "controllable" category of the federal budget, hence seem especially vulnerable when budget cutting is the order of the day. Certainly, managers of the federal budget, seeking to reduce total expenditures by tens of billions of dollars cannot be expected to treat science as a sacred cow. As it turned out, the nature, more than the magnitude, of the proposed reductions proved to be disturbing. Instead of proposing *pro rata* overall reductions, with the affected agencies given opportunity then to declare their priorities, they were directed, in successive prunings, markedly to reduce allocations to specific programs.

The scientific community will be grateful that the Office of Management and Budget (OMB) carefully preserved the central core of research and graduate education in the natural sciences, making only relatively nominal downward adjustments across government. Apart from eliminating such major new starts as the research instruments program, however, the programs selected for most other large reductions seem dictated not so much by financial constraints as by social philosophy. Thus, social science has been all but removed from the budgets of the National Science Foundation (NSF) and the National Institute of Mental Health (NIMH); the NSF education programs were virtually eliminated; the international programs of NSF were painfully shrunk; programs involving university-industry collaboration were eliminated; the institutional support component of National Institutes of Health training grants was deleted. Each warrants fair debate before the new Administration begins to implement its policies.

The NSF program for 'upgrading' laboratories by providing state-of-the-art instruments is long overdue; the obsolescence of our instruments limits the pace of the national scientific endeavor and, hence, limits the national future. The international programs of NSF support a small amount of bilateral cooperative research, exchange programs with China and the East European nations, dues to IIASA and the International Scientific Unions, *inter alia*. Surely this country is capable of sustaining a $14 million commitment to international partnership in the pursuit of knowledge and its beneficial applications. Severe, abrupt reductions in this program could have political repercussions out of all proportion to the sums involved.

The NSF educational programs are designed to improve education in science in every school system, not as support to routine operations. Particularly troublesome is the drastic reduction proposed for federal funding of research in social science. Patently, our knowledge of the natural world and our technology have outrun our wisdom in their use--witness the need for the very effort in which OMB is currently engaged. Agreed, the economists and sociologists have not enabled us to avoid our current national straits, but if the best of them are not assisted in their attempts to learn, we are doomed to cycles of well intentioned policies resting on flawed theoretical bases. If there is to be adequate funding for the social sciences, natural scientists and engineers must so urge.

As this is written, nothing has been heard from agency heads; they are silent as they should be. One can hope, however, that appropriately placed outsiders--the National Science Board and the Advisory Council of NIMH, for example--will make representations through channels and that scientists will later press their cases before Congressional committees, the opportunity for the scientific community to be heard.

One cannot know whether the presence of a Science Adviser in the White House might have affected the nature--not the magnitude--of these cuts. But there would have been greater assurance of understanding of what is at stake. Inevitably, major decisions involving science and technology will again present themselves in the White House. The President's need for a highly qualified Science Adviser will surely be at least as great as in the past. Announcement of such an appointment would be reassuring.

Philip Handler, President
National Academy of Sciences
Washington, D. C. 20418

[Whereupon, at 12:20 p.m., the hearing was adjourned.]

[Communications from Dr. Handler to the Director of OMB regarding proposed reductions for NSF, plus a statement from the Society of Hispanic Professional Engineers follows:]

NATIONAL ACADEMY OF SCIENCES

OFFICE OF THE PRESIDENT
2101 CONSTITUTION AVENUE
WASHINGTON, D. C. 20418

February 11, 1981

The Honorable John Slaughter
Director
National Science Foundation
1800 G Street, N.W.
Washington, D. C. 20550

Dear John:

The attached is self-explanatory. In the absence of a Science Advisor in the White House, this will ask that you attach this letter to the Director/OMB to such documents as NSF will surely be sending to him this week.

Sincerely yours,

Phil

Philip Handler
President

Attachment

NATIONAL ACADEMY OF SCIENCES

OFFICE OF THE PRESIDENT
2101 CONSTITUTION AVENUE
WASHINGTON, D. C. 20418

February 11, 1981

The Honorable David A. Stockman
Director
Office of Management and Budget
Executive Office Building
Washington, D. C. 20503

Dear Mr. Stockman:

I write to place before you some thoughts concerning the reductions in expenditures for certain scientific activities proposed by your office for both FY81 and FY82.

May I say immediately that it is understood that a reduction in overall expenditures must necessarily affect virtually all elements of the federal budget, including those relating to science. But I urge that those in the agencies encharged with such responsibilities be given opportunity to minimize the pain of such actions, to assure that important capabilities be slowed in pace rather than abolished, that great national assets not be dissipated, that in seeking to revitalize our economy by the macroeconomic impact of gross federal expenditures reduction we do not, unthinkingly, injure some program whose significance to the nation lies in other policy areas and is out of all proportion to the sum involved. Allow me to cite a few examples, based on my limited knowledge of the proposed budgetary rescissions.

1) It has taken several years of persuasion and the accumulation of much data to achieve inclusion in the NSF budget of $75 millions to upgrade instrumentation in the nation's laboratories. Instruments pace the capacity of the scientific endeavor; they determine what we can and cannot do. The long drought in science appropriations that began in FY67 forced the slow deterioration of our national stock of research instrumentation. The item in question is, in fact, long overdue. If you agree that this nation's scientific and technical capability is the great leverage we have in the world, our primary edge in global competition, commercial and military, you will agree that deletion of this item is a strategic blunder.

2) The proposed reductions in the NASA budget make real the concerns of those who, a few years ago, feared that the run-out costs of the shuttle would destroy space science. Indeed, these reductions seem to eliminate our program of planetary exploration and much else. But these programs also are a forcing function for American technology; they demand and thus lead to the creation of our most advanced technology while they have been a great source of pride to our people. I can understand large reductions that might slow down the pace of these programs. But I would hope that funds would yet be available that would permit the teams so engaged to remain in place and functioning.

3) I am a natural scientist, not always entirely sympathetic with the ways of social scientists. But I share their aspirations as must you, viz., sufficient understanding of our behavior, individually and collectively, as to enable us more rationally to manage our affairs. Patently, our knowledge of the natural world and our technology have outrun our wisdom in their use--witness the need for the very effort in which you now find yourself engaged. And it is in that light that I find myself troubled by the 75% reduction in funds for the NSF FY82 program for basic research in social and behavioral sciences (as I understand it, research in sociology, psychology, and economics). Agreed, the economists have not enabled us to avoid our current national dilemmas, but if the best of them are not assisted in their attempts to learn, then we are doomed to endless repetitions of well-intentioned policies resting on flawed theoretical bases. And the total sum involved scarcely looms as critical in the national accounts.

4) Finally, I find it necessary to alert you to the foreign policy implications of the cuts proposed for the International Division of the National Science Foundation. In this instance, however, I must indicate that a substantial fraction of these funds flow from the NSF to the National Academy of Sciences (NAS); hence, this institution is a party at interest.

The issue, however, is not the management of the funds, but the purposes they serve. I refer specifically to the exchange of scholars and scientists with the countries of

Eastern Europe--Poland, Hungary, Czechoslovakia, Romania, Yugoslavia, the GDR, and the USSR; similar exchange with the People's Republic of China; U.S. participation in the 17-nation International Institute for Applied Systems Analysis in Laxenburg, Austria; and American membership in the 18 constituent scientific unions and the parent International Council of Scientific Unions.

These programs which are managed on our national behalf by the NAS involve longstanding relationships with the nongovernmental scholarly bodies of some 72 countries. They have been built up carefully over the years; the International Council of Scientific Unions since 1935 (see PL 253, 74th Congress), the USSR since 1958, the countries of Eastern Europe since 1962-3, the International Institute for Applied Systems Analysis since 1970, and the People's Republic of China since 1972.

In addition, the NSF itself operates cooperative research programs with more than 20 countries. Some are those countries listed above; others include Japan, Mexico, and countries of Western Europe and South America.

Collectively these programs of scientific and scholarly interchange are of importance to the United States because they provide us with a window into the scientific workings of the closed societies, a means of cooperating with developing countries, and fruitful interchange with our industrialized allies. They constitute the substantive foundation for our international scientific diplomacy.

If these programs are reduced as proposed, it will send a signal to those seventy-some-odd countries noted above that with a gross national product of $2.5 trillions, with more than one-and-one-half million scientists and engineers, and with the highest levels of scientific and engineering productivity in the world, the United States is incapable of sustaining its $14 million commitment to international partnership in the pursuit of knowledge and its application for human betterment.

I am appalled at this prospect and I trust that, on second thought, you will be also. It is my hope that the proposed cuts can be deferred in order that we meet our international commitments this year. There is good reason to institute a serious, analytical look at the U.S. investment in all of international science and technology, intergovernmental and nongovernmental, during forthcoming months. We at the Academy are prepared to assist in such an analysis, to accept the results, and if it proves to be necessary or desirable, to contribute to a reduction of programs in an orderly fashion that can be explained to and understood by foreign countries and their scientific communities.

I have chosen but a few examples--and those from my limited knowledge of the total set of proposed actions. There may well be other specific actions that warrant a second look. Meanwhile, this will convey my appreciation and gratitude for the fact that, in addressing the NSF budget, you have carefully conserved what many have considered the vital core of the NSF program, i.e., project grant support in the natural sciences. Please understand, sir, that we are eager to cooperate, that we trust that the overall move to reduce the level of expenditures will rest on balanced policy considerations without regard to flawed sacred cows, but we ask that each action be of such pace and nature that federal agencies be enabled to protect the public interest as they go forward.

Sincerely yours,

P Handler

Philip Handler
President

NATIONAL ACADEMY OF SCIENCES

OFFICE OF THE PRESIDENT
2101 CONSTITUTION AVENUE
WASHINGTON, D.C. 20418

February 26, 1981

The Honorable David Stockman
Director
Office of Management and Budget
Washington, D. C.

Dear Mr. Stockman:

Dr. Roger Levien, Director of the International Institute of Applied Systems Analysis in Vienna, Austria, has just brought to my attention a telephone call he has received from the U.S. Embassy in Austria. Our understanding of this telephone conversation is as follows:

> NSF budget for international programs has been cut by 40% for fiscal year 1982. $3 million for support of IIASA is explicitly eliminated from that budget, The balance remaining in this general budget category is for multilateral and bilateral programs. The Western European bilaterals are to be saved. OMB requested the U.S. Embassy in Vienna to make any reply it wishes by tomorrow morning. After that, the books are closed at OMB.

You should be informed that IIASA is a non-governmental, multi-national autonomous, scientific institution established as a corporation under Austrian Law. At the request of the government of the United States in 1969, the National Academy of Sciences participated in the creation of this institute and serves as the U.S. national member organization. The annual financial obligation to IIASA and support of Academy oversight by the IIASA scientific program have been funded by NSF in accord with the instructions to NSF by President Nixon in 1969. [See attachment.]

Negotiations for the financial commitments of membership under the terms of the IIASA charter have been carried out with the full knowledge and advice of the U.S. government. At present, we are in a three-year cycle of financing, terminating December 31, 1982, to which the Academy has made membership commitments which were formally authorized by the U.S. government.

Article IV, Section 5 of this charter reads as follows:

> After its fifth year of membership, a member institution may resign from the Institute by giving one year's notice at the end of the current fiscal year. Any member institution so resigning shall be liable to the Institute for financial obligations incurred pursuant to membership until such obligations have been discharged.

In light of this commitment by the National Academy of Sciences, made with the full knowledge and approval of the U.S. government, failure to meet the U.S. commitment for the year 1982 presents serious financial problems for the Academy, and foreign policy implications for the U.S.

If the proposed action takes place, the Academy will be forced to give notice of its resignation as a member of IIASA, despite the facts that: IIASA has met all tests of its scientific value; IIASA has well served, as originally hoped, as an apolitical meeting ground where American, Soviet and other scientists could work together on problems of mutual interest and concern; IIASA is the only multilateral institution in which the U.S. and the U.S.S.R. pay exactly equal contributions in hard currency; and that the Government of Austria has invested more than $10 millions in the physical plant for the Institute on the good faith assumption that the U.S. and U.S.S.R. would continue support of the Institute. Withdrawal will surely be regarded as a political act by the Soviet government, the other principal founder of IIASA. Since the founding, this Academy and the Soviet Academy have nominated the Chairman of the Council and the Director of IIASA; indeed we are currently engaged in recruiting the next Director.

It is with profound concern that I underscore the seriousness of the implications of U.S. withdrawal from IIASA membership. I urge that the Administration reconsider the proposed termination of support for 1982.

Sincerely yours,

P Handler

Philip Handler
President

cc: The Secretary of State
The Director, National Science Foundation
Assistant to the President for National Security Affairs

Proposed:

THE WHITE HOUSE
WASHINGTON

CONFIDENTIAL

October 7, 1969

MEMORANDUM FOR

Dr. William D. McElroy
Director, National Science Foundation

I wish to commend to you the proposal for creating a non-governmental East-West Institute of Applied Systems Analysis which you have discussed with McGeorge Bundy of the Ford Foundation and members of my staff.

I believe this enterprise deserves the support of this Government. I herewith designate the National Science Foundation as the responsible agency for providing appropriate financial and administrative support to the Institute.

I am aware that further steps are necessary before establishment of the Institute is assured, but I believe that the prospects are sufficiently promising to justify your now beginning consultation with the Bureau of the Budget and with proper committees of the Congress for the purpose of obtaining the necessary additional support in FY 1971.

CONFIDENTIAL

The Society of Hispanic Professional Engineers

POST OFFICE BOX 48 MAIN OFFICE LOS ANGELES, CALIFORNIA 90053

March 13, 1981

The Honorable Doug Walgren, Chairman
Science, Research and Technology Committee
117 Cannon House Office Building
Washington, D.C. 20515

Dear Congressman Walgren:

The enclosed statement was prepared to share with you the views of The Society of Hispanic Professional Engineers (SHPE) regarding the Administration proposal for the National Science Foundation Fiscal Year 1982 Authorization Budget. We are very concerned that the science and engineering education programs are being virtually eliminated.

As the largest professional technical Hispanic society, we are dedicated to increasing the number of professionally trained Hispanic engineers and scientists. In addition, we share a broader concern, which is the future of science education in this country.

We recognize your busy schedule, but we would appreciate it if you would take a few minutes to review our statement.

Thank you for your time.

Sincerely,

Richard Jimenez

Richard Jimenez
Second Vice President
of the Executive Board

RJ:slw
Enclosure

cc: Dr. Alvin D. Rivera
SHPE Washington, D.C. Representative

The Society of Hispanic Professional Engineers

POST OFFICE BOX 48 MAIN OFFICE LOS ANGELES, CALIFORNIA 90053

STATEMENT ON THE ADMINISTRATION
PROPOSAL OF
THE NATIONAL SCIENCE FOUNDATION
FY 1982 AUTHORIZATION BUDGET

To

THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C.

March 16, 1981

The Society of Hispanic Professional Engineers is very concerned about the cutbacks proposed by the Administration regarding the National Science Foundation (NSF) FY 1982 Authorization Budget. These cutbacks come at a time when minorities preparing for the technical career fields are slowly on the increase. At the same time, the partnership between the Federal Government and the private sector is just "beginning" to tap the new frontiers of technology through their efforts of science education, research, development and innovation.

All the data to date suggest a serious shortage of trained engineers and scientists in the nation. While minority enrollments are increasing slightly in these fields, Hispanics in this country are showing the least progress. The most dramatic increases were for women in the technical fields. According to the Scientific Manpower Commission, the following information was reported (Manpower Comments, March 1981):

- Blacks were 2% of freshman engineers in 1970 and are 6% in 1980, while their share of earned bachelor's degrees has risen from less than 1% to 2.3% during those years.
- Hispanics were .6% of the entering medical class in 1970 and only 1.5% in 1980. Their representation in medical school facilities is still below 1%.
- Minorities (American Indians, Asians Americans, Blacks and Hispanics) are 18% of the U.S. population, and earned 8.2% of all U.S. doctorates awarded in 1980.
- In medicine, the proportion of women among graduates has risen from 8.5% in 1970 to 23% in 1980; in dentistry, from 1% to 12%; and in engineering from 1% to 10%.

These data confirm the recent passage of the Women in Science bill should have emphasized a greater role for minority participation. We believe a stronger and more targeted commitment of the Congress is necessary to resolve the under-presentation of minorities and women in these scientific and technical fields.

Much of the progress of increasing the number of minority engineers is attributed to selective federal programs and financial commitments of approximately 40 industries and foundations. As working Hispanic engineers and scientists, we believe that the federal role is vital in this effort. Federal programs have stimulated cooperation with community, schools and professional organizations to encourage minorities to become interested in the technical field. These federal programs have also created the incentives for industry and foundations to invest its own resources to improve minority participation in the technical field. While there is a continued need to improve the relationship between the government and industry in this effort, it is questionable if industry would sustain their commitment if the Federal government terminates its involvement.

The Society of Hispanic Professional Engineers (SHPE) fully endorses the past role and contributions of the NSF, and particularly the programs in the Science Education Directorate. The successful 30 year history of NSF and its functions in Science Education should be continued and improved.

The Society has a college student chapter membership of nearly 1,000 Hispanics in 25 colleges and universities around the nation who represent our future engineers and scientists. These students depend either directly or indirectly on the resources provided from the National Science Foundation with its broad charge to support Science and Engineering Education and Research. While the primary goal of SHPE is to increase the number of Hispanic engineers and scientists, we are very concerned that by totally eliminating the money for the Science and

Engineering Education programs, it would seriously reduce the flow of future persons trained in technological fields.

The SHPE membership of nearly 200 Hispanic professional engineers and scientists has a broader concern for the future of Science Education in the United States. Our nation has maintained a competitive leadership role in the world regarding science and technology. Certainly much of the credit goes to the Congress for providing the resources to the National Science Foundation to carry out its duties. At a time when this nation and many of the other nations in the world are becoming increasingly dependent upon new technologies, one has to be concerned about what we are doing to maintain the scientific community that has provided that "competitive edge" we currently enjoy. There is a need for a renewed vision of Science Education in America. We are fearful that eliminating the Science Education programs in NSF is not the solution.

We are mindful of the progress of other nations, such as, Japan and West Germany and their contributions to technology. We are also mindful of their leadership role in this area. For this reason, we believe the United States should be increasing its commitments to science not reducing it. Correspondingly, the statute of this nation and its future will rest on our ability to maintain a competitive role in science in the world. If this leadership role is allowed to deteriorate, the effects may likewise result in a deterioration of our nation's security. Thus, the Administration's proposal regarding the NSF budget would put more than just the future of Science Education in jeopardy.

Perhaps no group of Americans is more aware of the state of the economy than Hispanics. Hispanics are among the most needy and most underserved population in our society today. We share the concern of the Administration and the Congress for an improved national economy, but not at the expense of science. We wish to echo the lingering thoughts of Congressman Doug Walgren regarding the NSF Authorization Hearings of March 10, 1981:

> We live in a society that is clearly dominated by science and technology. Our national survival and perhaps even our survival as a species, may well depend on how well we understand and use the tools and the products of science. Our short term decisions must be made with that long term truth in mind.

○